MASSACHUSETTS - Commissioners on the Troy and Greenfield Railroad

Annual report, for 1866.
(House Doc. no.30)

ANNUAL REPORT

OF THE

COMMISSIONERS

ON THE

Troy & Greenfield R.R. and Hoosac Tunnel,

TOGETHER WITH THE

REPORTS OF CHIEF AND CONSULTING ENGINEERS.

BOSTON:
WRIGHT & POTTER, STATE PRINTERS,
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HOUSE..... .....No. 30.

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Commonwealth of Massachusetts.

COMMISSIONERS' REPORT.

To His Excellency the Governor, and the Honorable the Executive Council of the Commonwealth of Massachusetts.

The Commissioners on the Troy and Greenfield Railroad and Hoosac Tunnel respectfully submit herewith a statement on the condition of that work, December 1st, 1866.

The money on hand at the date of the last report was,		$12,491 44
Received since, to December 1, 1866,		590,000 00
For materials and supplies beyond the sum deducted from pay-rolls,		30,603 13
For salaries of Commissioners, 15 months, to September 1, 1866,		7,216 71
		$640,311 28
They have furnished vouchers for payments amounting to,	$626,815 80	
And for their salaries,	7,216 71	
		634,032 51
Leaving a balance in their hands of,		$6,278 77

They are chargeable with the following amounts:—

Cash on hand, December 1, 1865,	$12,491 44
Supplies and materials stated to be on hand at that date,	35,447 59
Money received from the State treasurer,	590,000 00
	$637,939 03

This is accounted for as follows:—

Amount expended on buildings, machinery, and fixtures,	$179,569 59
On the work of construction,	411,334 51
Cash on hand,	6,278 77
Leaving, as supplies unsold, and materials not charged to the work, the sum of	40,756 16
	$637,939 03

Of the items composing the last amount, an inventory is being taken, with a view to the disposal of all stock in the stores, as well as of the business of store-keeping.

For information relating to the cost, progress, and condition of work upon the tunnel, we refer to the accompanying report of Thomas Doane, the present chief engineer, appointed by the Commissioners in 1863.

The selection by you, in August, of Benjamin H. Latrobe, Esq., of Baltimore, as consulting engineer, is likely to prove useful to those intrusted with the conduct of the work. He is a gentleman of large experience, of excellent judgment, and eminently practical in the treatment of subjects presented for his consideration. His suggestions regarding the methods to be adopted hereafter, commend themselves alike to men of the same profession and to the skilful miner, and his desire to render available whatever has been provided as auxiliary to the plans of the Commissioners will tend to avoid the waste which might otherwise arise from the proposal of important changes.

In July last, proposals were made by the Fitchburg and the Vermont and Massachusetts Railroad Companies to lease the railroad from Greenfield to its terminus in the town of Rowe, near the eastern entrance to the tunnel, at an annual rental of $30,000; this lease to continue in force until the completion of the tunnel, unless that work should be suspended by competent authority. Such lease was subsequently executed, under the direction of the attorney-general.

After amending the line in many of its details, lessening the curvature, and improving the location of some of the bridges,

the construction of the road was, on the 8th of October, with your approval, and under the advice of Mr. Latrobe, put under contract, to be completed for the sum of $545,000. This does not include depot buildings, turn-tables, nor engineering expenses, which are estimated at an additional sum of $45,000, and it is believed that the entire cost will not exceed $600,000.

The contract provides for the opening of the road to Shelburne Falls by the 15th of November next, and throughout its remaining distance by the 15th of the following July.

About the middle of June, the automatic drills, referred to in previous reports, were introduced into the heading at the East End. For a few weeks, their operations were attended with reasonably satisfactory results, and they gave promise of complete success whenever the workmen should become familiar with this new system of drilling. Gradually they began to fail in strength; the incessant and rapid blows—counted by millions—to which they were subjected, appearing to granulate or disintegrate portions of the metals composing them, so that, in consequence of frequent changes for repairs which were found to be necessary, it became evident that these machines would prove of little practical value.

Having been produced by years of the combined ingenuity and toil of skilful men, at large expense to the State, after costly preparations in the river and on the mountain, and endorsed as they had been to some extent by the legislature of the Commonwealth, it was decided to employ them long enough at least to furnish the most satisfactory test of their capability for this service.

For these reasons, they were kept in use for six months, the expenses of operating being greater than those required by hand labor, and the progress during that period smaller than could have been made by the ordinary method of manual drilling.

At the time the conclusion was reached that these machines would not be able to meet the requirements needed for work upon the tunnel, the attention of the Commissioners was called to a new power-drill, which appeared to be free from the objections which had disclosed themselves in the one then in use.

As this drill could readily be adjusted to a carriage which had been prepared at great cost, and as its trial would involve no further expensive outlay for other necessary appliances, these having been already provided, it was though advisable to continue the organization for working by machinery for a few weeks longer, until the value of this system could be thoroughly ascertained.

Four drills of the new pattern have recently been brought into use, with flattering indications of success; but until eight or ten can be kept steadily at work in one of the headings, it will be unwise to promise ourselves that every difficulty in this direction has been surmounted.

The adoption of machinery necessarily leads to the employment of a more skilful class of labor, and the saving is likely to be in time only, which may lessen the accumulation of interest on the great outlay required for the prosecution of the work.

The value and economy of nitro-glycerin as an explosive seems to have been fully demonstrated, and the method of using it with safety to the employees appears to be the only question now undetermined. Its early introduction is very desirable, and preparations are making to bring this about whenever it shall appear to be prudent to do so, since it is believed, on the strength of numerous experiments made in the tunnel at the West End, that by the use of this agent alone, as compared with gunpowder, the time required for completing the work may be greatly reduced.

Inquiries regarding the value of other substances used in blasting have been made, and it is not improbable that something may be provided as effective as glycerin, without its attendant dangers.

The system of exploding simultaneously by the agency of electricity appears to possess many advantages, and provision has recently been made for its early adoption upon every section of the work.

In order to produce rapid progress we are not necessarily dependent upon the use of power-drills, which, while they may give great promise of usefulness, are also liable to bring disappointment by the development of some hidden difficulty.

Various opinions are entertained regarding the expense to be incurred and the time consumed in completing the tunnel, and it may not be unwise to estimate these matters in what seems to us their most discouraging aspect.

It appears to be quite certain that, with the usual instrumentalities which have been furnished during the last three years, and without any aid from the Central Shaft, at headings from the two ends alone, 125 feet per month, or 1,500 feet per year, can be gained. This rate has been accomplished during several months of the present year. The distance between the two points is 18,000 feet, and to overcome that would, at the above rate, require just twelve years. The western section can be completed many years earlier, and this when done will effectually provide for the troublesome influx of water which is likely at times to retard operations from the West Shaft. The use of power-drills and newly invented explosives may very much reduce this period, or compensate at least for such occasional delays as will occur; while persons of practical and intelligent minds believe that, by the employment of nitro-glycerin, simply as an auxiliary to hand labor, this estimated time may be shortened one-half.

Of the cost, it can be stated that, in the decomposed formation at the West End, a brick and stone tunnel is now being built, for a portion of the distance by contract, at $400 per lineal foot. It is known that this formation does not extend beyond 1,900 feet, and there is good evidence tending to prove that it will hardly reach one-half this distance. The outlay for the whole of this section, then, need not exceed $760,000. The distance between the heading at the East End and the heading at the West End is 18,000 feet. This heading comprises 60,000 cubic yards, which it is confidently believed can be taken out for less than $15.00 per yard, or $900,000. There would then remain of enlargement, on the present plan, and this may be somewhat reduced, 300,000 cubic yards, which could be let out at the present time at $6.00 per yard, or $1,800,000. From the West End to a connection at North Adams with that part of the railway now in operation, the construction of the road, land damages, and enlargement of the small tunnel at that point, should not exceed the sum of $150,000. This shows that the entire amount necessary to be expended hereafter, without

interest, might reach the sum of $3,610,000, in the present currency of the country, with a strong probability that the amount would be greatly lessened by an improved condition of the finances, and its consequent effect upon the prices of labor and materials. The present section of the tunnel, containing $18\frac{4}{10}$ cubic yards for each lineal foot, is one of very convenient form; but its usefulness could not be seriously impaired should it be made to contain but 17 yards, the difference being, at $6.00 per yard, nearly $200,000.

These estimates are not based upon any prices heretofore paid for work upon the tunnel.

From the best information to be obtained, the cost of taking out the heading, under the system pursued for three years past, cannot have been less than $30 per cubic yard; and yet we have become satisfied that individual enterprise can accomplish better results than those indicated by the above calculations. Other work of a character quite as difficult has been performed at even lower rates.

Of the amount expended since the appointment of Commissioners in 1862 to Nov. 1, 1866, $957,899.75 have been disposed of in the erection of a dam, wheel-house, and other buildings; in the purchase of land and machinery; in payments to engineers and for excavations at the west approach; leaving, for operations upon the rock in the tunnel and shaft, $525,073.45. For this latter sum, 21,000 cubic yards have been removed, at an average cost of $25 per yard.

For the first-named objects, large appropriations will not be requisite hereafter; and in the future management of the enterprise expenditures may be confined to the most expeditious and economical means of reducing the distance yet remaining to overcome.

The Sand Patch Tunnel, on the Pittsburg and Connelsville Railroad, through one of the Alleghany Mountains, 18 by 16 feet, about a mile in length, a large portion built during the present year, the heading nearly complete, composed of very hard sandstone, lying more unfavorably for blasting and quite as hard to drill, as the rock of the Hoosac, has thus far cost but $4.16 per cubic yard, including heading. Other tunnels, of

smaller dimensions, have been made at rates as low as this, and it is reasonable to assume that the work we are engaged in can be performed by the aid of private enterprise at a price within the estimates herein presented.

The Central Shaft is located between the two spurs of the mountain; its position has been determined by repeated observations. Until it reaches grade no engineering beyond the use of the plummet appears to be required, and the work upon it may be contracted for with no greater objection than would exist if it were situated in any other town in the State.

The East End is equally independent of other sections of the work; is thus far free from water or other obstructions, and may be pursued with hammer and drill and powder, so long as the line and the level are furnished to the miner.

At the West Shaft greater difficulties present themselves, and practical engineering skill is requisite; but should the State relieve the miner from the delays and expense which are incident to the influx of water, a favorable contract might be made for completing large portions of this section of the tunnel.

At the extreme west end, the work, under private supervision, is progressing satisfactorily, and while heretofore this seemed to be environed with insurmountable obstacles, beyond the ability of public servants to overcome, an individual contractor has, by his energy, determination and skill, been able to furnish the best evidence of ultimate success.

Under the law of 1863, the Commissioners can make no contract exceeding $10,000 in amount, but the statute enacted in May last provides that the governor and council shall have the general supervision of the work, and as we believe that its most economical and speedy completion can be more certainly assured by inviting competition, and that better results in other respects are likely to follow, we recommend that the manner of conducting it be changed, and that the Commissioners be directed to contract the different sections of the work to competent parties, having due regard to the present financial condition of the country, and the prospect of more favorable terms prevailing in the future.

Whatever plan may be agreed upon, in order to continue work both upon the railroad and the tunnel throughout another year, a further appropriation will become necessary.

It is neither our duty or desire to comment on the antecedent history of this enterprise, but if, in the progress of the work, mistakes have been made, or unnecessary expenditures permitted, it will be borne in mind that these have occurred during an unsettled period of our national affairs, when the most extravagent prices were demanded, exaggerating even the errors which seem to be incident to the execution of every important undertaking.

The illness of Mr. Brooks, the former Chairman of the Commission, since May last, his resignation and that of his associate, Mr. Holmes, in August, and the prior resignation of Mr. Felton, having placed the work in the hands of the undersigned, they have aimed only at furnishing such information regarding its present condition as a limited connection with its management enables them to do, fully impressed with the belief that numerous costly arrangements for a systematic and vigorous prosecution of the work being already provided, under proper direction a removal of the barrier now existing between the two ends of the Hoosac Tunnel is no uncertain problem.

JAMES M. SHUTE,
ALVAH CROCKER,
CHARLES HUDSON,
Commissioners.

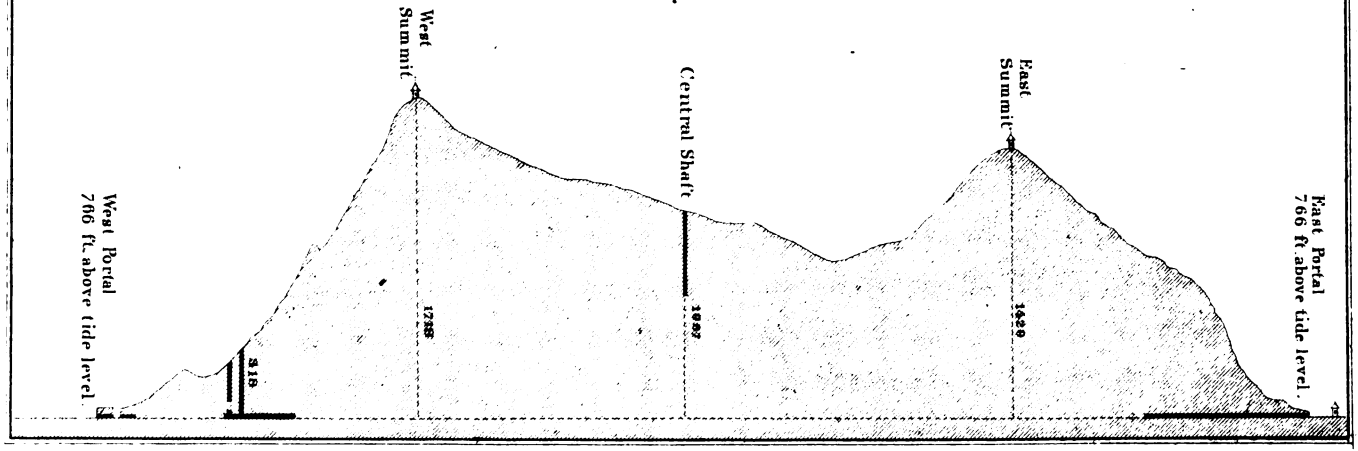
BOSTON, December 26, 1866.

DIAGRAM N°. 4.

PROFILE
OF
HOOSAC MOUNTAIN.

Hor.l Scale 4000 feet to 1 inch.
Ver.l " 1000 " " "

Length of Hoosac Tunnel when finished			25.586.0 feet
Dec.r 1. 1866	E. End heading	3473 0.	
" " "	E. heading W. Shaft	1.042 0.	
" " "	W. " " "	298 0.	
" " "	W. End heading	1.010 0.	
			5823.0
		Balance	19763.0
Depth of Central Shaft when finished			1037.0.ft.
Dec.r 1.st 1866		down	377.2. "
		Balance	659.8. "



REPORT OF THE CHIEF ENGINEER.

NORTH ADAMS, Dec. 19, 1866.

To the Commissioners of the Troy and Greenfield Railroad and Hoosac Tunnel, JAMES M. SHUTE, ALVAH CROCKER, and CHARLES HUDSON, this Report, concerning the progress upon the Hoosac Tunnel for one year subsequent to the time covered by my report dated Dec. 15, 1866, is respectfully submitted.

As all the members of the Commission under its original organization have left the Board, and as from this Board I received the appointment of Chief Engineer, it seems fit that I should here thank them for the generous support and kindly feeling extended to me during a period of nearly three years.

Having said to you that some other person might be your choice as Chief Engineer, you were kind enough to reply that you desired me to retain the position.

Hoping that this relationship may not be less pleasant than the former one, and that under your direction this great work may be economically and expeditiously carried on, I proceed to the details of my Report.

LINE.

Within the last year two more of the stone instrumental station-houses have been put up; one at the East End, near the Portal, and another upon the mountain west of the Tunnel. This last is upon private grouud, by permission of the owners, Messrs. L. L. Brown & Co., of South Adams.

The transit instruments referred to heretofore have been completed by J. H. Temple, of Boston, and by means of them

the line has been again worked up, until it is believed to be sufficiently near, over ground, for all practical purposes.

Upon the completion of the Tunnel to the West Shaft, it will probably be necessary to erect another station at the West End, just outside the Portal.

As this event is distant some years, and as the base line available at the foot of the West Shaft is less than eight feet long, it was foreseen a year ago that some provision must be made for a longer base by means of which the line could be run both east and west more accurately. It was therefore determined last December to sink a new shaft at a point 264 feet west of the West Shaft, and the work was at once entered upon. As the penetration east will probably be 4,000 feet before the West End work reaches that from the West Shaft, the necessity for this is made apparent.

Under the head of Supplementary Shaft the reasons will be given why a shaft was chosen rather than a boring, and a statement made of progress in sinking it.

Location and Right of Way.

The location of the Tunnel has been made, and it is now possible to report that a right of way not less than five rods wide has been secured through its whole length, in part by the purchase of farms.

Labor.

This has been, as heretofore, under the more especial charge of Mr. Hill.

A good Providence has watched over the health of our men, and has vouchsafed total exemption from accidental injuries.

Contentment and consequent order and quiet have prevailed. Wages remain as reported last year; viz., in the various headings and down the Central Shaft, $2.25 per day of eight hours, and outside, $1.50 for ten hours.

The system of statistical information concerning labor performed and material used has been kept up, it is believed, with advantage to the work. In addition to their previous duties, the statisticians have learned and practised, as far as material has been provided, the simultaneous firing of both powder and nitro-glycerin charges.

The system of store-keeping as originally established has been maintained, and the following table gives the monthly collections for supplies at the various stores.

Amounts collected Monthly for Supplies during the Year, from November 1, 1865, *to November* 1, 1866.

DATE.	East End.	Central Shaft.	West End.
November, 1865,	$3,287 66	$707 90	$3,088 42
December, 1865,	2,191 63	798 39	3,118 13
January, 1866,	2,051 17	798 54	3,001 42
February, 1866,	1,901 87	587 43	3,725 51
March, 1866,	1,941 31	553 73	4,174 11
April, 1866,	1,811 51	547 75	4,218 16
May, 1866,	2,042 23	545 17	4,542 62
June, 1866,	2,343 22	740 00	4,822 57
July, 1866,	2,084 33	598 85	5,166 67
August, 1866,	2,069 86	787 04	5,130 30
September, 1866,	1,941 28	919 02	5,031 84
October, 1866,	1,887 96	1,040 38	4,782 48
	$25,554 03	$8,624 20	$50,802 23
			8,624 20
			25,554 03
Total amount,			$84,980 46

There have been tenements erected during the past year as follows:

At the West End one has been put up for the accommodation of the brickyard men.

At the West Shaft, eight for the miners, one for the blacksmith, and a double cottage for the captain.

At the Central Shaft, two tenements have been built for the miners.

At the East End, a cottage has been put up for the resident engineer at that place, and a tenement for one of the mechanics

Under the contract made by the Commission with B. N. Farren, and dated May 1, 1866, he was to have such tenements

at the West End as he needed, and by his right he has, among other buildings, taken fifteen tenements there.

This made it necessary to put up at the West Shaft the eight for men who had before occupied those taken by Mr. Farren.

The following table shows the monthly collections of rents at the various parts of the work for one year.

Amounts collected Monthly for Rents during the Year, from November 1, 1865, *to November* 1, 1866.

DATE.	East End.	Central Shaft.	West End and West Shaft.
November, 1865, . . .	$177 43	$39 00	$128 50
December, 1865, . . .	144 02	39 00	124 50
January, 1866, ...	135 50	41 84	192 32
February, 1866, . . .	136 50	43 00	144 27
March, 1866, ...	132 00	43 00	176 41
April, 1866, ...	135 00	38 71	206 33
May, 1866, ...	125 00	55 34	172 45
June, 1866, ...	124 00	53 00	186 55
July, 1866, ...	131 00	51 27	127 83
August, 1866, ...	129 50	54 50	166 37
September, 1866, . . .	118 99	57 00	151 41
October, 1866, ...	105 75	48 29	119 00
	$1,594 69	$563 95	$1,895 94
			563 95
			1,594 69
Total amount, ...			$4,054 58

By comparison with the building accounts, excluding the general one, it will be seen that the rents collected for dwellings, stores, &c., amount to $4\frac{84}{100}$ per cent. of the total cost of *all* buildings, including machine shops, shaft houses, barns, carpenter and blacksmith shops, powder houses, &c., for which no rent is received.

The dwellings probably pay an annual rent of about 10 per cent. on their cost.

The following table gives the various kinds of buildings, their numbers, and, in general, the rents received for each:—

	East End.	Central Shaft	West Shaft.	West End.	Yearly Rent—Each.
Boarding-house, East End,	1	–	–	–	–
" " Central Shaft,	–	1	–	–	$120 00
" " West Shaft,	–	–	1	–	72 00
" " West End,	–	–	–	1	150 00
Cottage, double,	1	–	1	–	150 00
" single,	1	–	–	–	–
" "	1	–	–	–	60 00
Mechanics' and Foremen's tenements, double,	–	4	3	–	72 00
" " " " single,	7	–	1	2	60 00
Laborers' 1st class, double,	17	7	8	26	48 00
" " single,	2	–	–	–	12 00
" 2d class, double,	–	–	4	–	48 00
Old store, converted into lodgings,	1	–	–	–	72 00
Stores,	1	–	–	1	150 00
"	–	1	–	–	100 00
Barns,	2	1	–	–	–
" in part rented to Farren,	–	–	–	1	50 00
Carpenters' shops,	1	1	–	–	–
Carpenter shops, in part rented to Farren,	–	–	–	1	60 00
Blacksmith shops,	1	1	1	–	–
" " in part rented to Farren,	–	–	–	1	25 00
Machine shops,	1	1	–	–	–
Saw-mills,	1	1	–	–	–
Offices and store-houses, engineers and supt.,	2	1	1	–	–
" rented to Farren,	–	–	–	1	15 00
Powder houses,	2	1	1	1	–
Gate houses,	2	–	–	–	–
Iron sheds,	1	–	–	1	–
Coal sheds,	1	–	1	–	–
Wood sheds,	–	1	–	–	–

	East End.	Central Shaft.	West Shaft.	West End.	Yearly Rent—Each.
Shaft and engine-houses, last being temporary,	1	1	2	–	–
Brick-yard, kiln shed, ...	–	–	–	1	–
	47	22	24	37	–
				24	–
				22	–
				47	–
Engineer's office and barn, North Adams, ...				2	–
General freight house, North Adams, ...				1	$150 00
Coal shed, North Adams, ...				1	75 00
W. End & W. Shaft fr'ght house, on side track P. & N. A. R. R.,				1	–
Instrumental houses, ...				4	–
				139	–

On the 31st of October, 1866, there were employed, 116 men at the East End, 83 men at the Central Shaft, 134 men at the West and Supplementary Shafts, 18 men about the brick-yard, and about 100 men at the West End, under B. N. Farren's contract, making a total in the State's employ of 351, and, including Mr. Farren's, 451.

P. W. Smith has acted as agent for purchasing supplies and materials during the year; and Warren Stetson, very much to your acceptance I believe, was cashier until October, when Henry C. Cunningham took his place, and assumed his duties with some others additional.

Machinery.

The three portable engines belonging to the State are still on hand.

The 14-horse engine has been used most of the year to assist in sinking the Supplementary Shaft.

The 10-horse engine has been used for a time at Well No. 4; and is now driving a 5-inch plunger pump at the Supplementary Shaft.

The 7-horse engine has been used during the summer at the wheelpits in pumping water and running a derrick, and has since, with a centrifugal pump, been hired out for a short time, and is now laid up.

Our two saw-mills, one driven by water-power at the East End, and the other by steam at the Central Shaft, have proved most useful and economical to the work.

The hoisting apparatus built for the Central Shaft at the Lowell Machine Shop, has been set up and is working finely. In connection with this there is an air compressor of two cylinders, made by James Hunter and Son, similar to those at the East End, of thirteen inches in diameter and twenty inches stroke, but set vertically, all ready for work, either in driving drilling machines or in ventilating.

At the West Shaft another air compressor of four cylinders, of similar size and setting, has been for some time nearly ready for power or ventilation.

The air compressor of four horizontal cylinders, thirteen inches by twenty inches each, referred to in my former report, as about ready for use at the East End, has been at work day and night without cessation, except on Sundays, since March. It was intended to compress air to sixty pounds per square inch, and has run it up as high as eighty-five pounds; but as the drilling machines require air at only about thirty pounds pressure, it has generally been run at that pressure. It was intended for a speed of one hundred and twenty revolutions per minute; but as it can easily supply all our drilling machines, nine having been the highest number, at a speed of seventy revolutions, it has not usually been run faster.

This compressor, making seventy revolutions, will furnish 148.01 cubic feet of air per minute, at a pressure of forty-two pounds.

Another air compressor of four horizontal cylinders, twenty-five inches diameter by 24-inch stroke, has been set up at the East End. This is intended simply for ventilation, and will probably not be run at a higher pressure than five pounds per square inch. Making eighty revolutions per minute, it will furnish 2,181.3 cubic feet of free air per minute, which will fill 24.23 feet of heading or 4.39 feet of full size tunnel per minute.

It is now being run about two hours after each blasting, and furnishes all the ventilation necessary for the present.

In addition to a small air compressor of three cylinders of 8-inch by 12-inch stroke which has been on hand some time, we now have two other similar ones made by Harrison Loring, intended for special use in case the local ones break down. These can easily be transported from place to place, and be run by belts, in readiness for this purpose.

In addition to the tools mentioned in my last report, we have since procured of the Putnam Machine Company a larger engine-lathe, and a hand-lathe; both of which, with the others, are in constant use.

I have advised to put into the Supplementary Shaft two bull engines, having steam cylinders of thirty inches diameter, plungers of thirteen inches diameter, and a stroke of ten feet for both piston and plunger.

This is the most economical engine for pumping, and being regulated in the frequency of its strokes by a cataract, it can be exactly adjusted to the variable and increasing quantity of water. This is not true of any other engine adapted to this work, as if too large for present purposes it will waste fuel, and if too small for future requirements, it must be replaced by larger.

Messrs. H. G. Burgess and John Christiansen have most acceptably filled the respective positions of master mechanic and mechanical draughtsman, and the satisfactory working of this department has been in a great degree due to their ability and watchfulness.

Drilling Machines.

An automatic machine able to do the drilling necessary in driving the Tunnel, at a saving in cost and time over the manual system which requires such hard and persistent labor, and which if it could be found would be the key to the whole system of progress and economy in tunnelling, has been most assiduously sought.

The point was early decided that such machines must be pneumatic, as it was found to be utterly impracticable to run them in headings far beneath ground, by steam.

The former Chairman of the Board gave himself especially to this problem, and with the help of mechanics, devised and brought out a machine, of which from thirty to forty were introduced into the East End heading in June last, and which have done all the work reported upon in the tables of machine work. They were beautiful machines, light in weight, compact in form, and automatic, but proved themselves in a few days to be deficient in the very necessary quality of strength. As I learn from the foreman of the East End shop, Mr. William Hall, they are made up of eighty parts and weigh about 240 pounds each. They cost about $400 apiece.

It is not agreed among mechanics whether they can be made sufficiently strong to become an economical tool. Our mechanical draughtsman has made a suggestion to this end which is quite worthy to be followed out.

The progress made has been with from one to nine machines, probably an average of three machines, working through the time given to drilling.

There have been 979 of these machines sent out of the heading for repairs, and the following table gives the principal parts which have failed.

Table showing the Number of Principal Parts of Drilling Machines broken, up to Nov. 1, 1866.

Crossheads,	59
Cylinder flangs,	18
Coupling nuts,	28
Feed nuts,	39
Feed springs,	415
Feed palls,	90
Ratchet covers,	163
Screw spindles,	19
Shields,	14
Tappet bars,	120
Union coupling nuts,	26
Valve stems,	27

It will be seen that the breakages are confined prominently to two parts, one of which is a simple and inexpensive spring.

Had a sufficiently large number of machines been provided, so that twelve had been constantly in order for use, as was intended, it cannot be doubted that a progress which with three machines almost reached that made by hand, would have been very much increased. But, under the existing circumstances, machine drilling has been prejudicial to progress and very expensive.

An improvement upon the first machine, perhaps indeed a new machine, has been invented by a member of the Putnam Machine Co., C. Burleigh, and several of them have been introduced into the heading since Nov. 1, 1866. It is made up of the same number of parts as the first machine, is inferior to the first in compactness, weighs 372 pounds, and is not practically automatic as yet.

It has not been long enough at work to test its qualities. The two machines drill at about the same rate, but the second one is likely to prove much more durable than the first.

While the reports of East End progress and cost are unfavorable in regard to the use of machine drills as heretofore constituted, and far from satisfactory to those who invented them, and perhaps discouraging to many friends of the enterprise, who hoped by a successful machine to overthrow all reasonable opposition, it may still, I think, be expected that either the machine of Mr. Burleigh, now on trial, in which he expresses the utmost confidence, or some improvement upon it, will prove to be the thing sought for.

Of all the reciprocating machines brought to your notice, that of Mr. Burleigh seems to me most promising.

The annular diamond drill is also worthy to be considered as one which avoids the concussion consequent upon reciprocation, having itself a rotary movement, and being able to begin its boring without any previous preparation of the face of the rock.

I can but express the hope that so influential and wealthy a Commonwealth as Massachusetts, may justify you in a most liberal and enlarged policy in this respect, which shall give these and other machines an opportunity to be developed.

I think further experiments should not be made in the headings, nor with a great number of the same kind of machines,

which is unnecessarily expensive, but in a shop, and with single machines.

A large outlay, which should soon result in a machine able to run a month without a break, would doubtless be many times repaid to the State in the construction of the Tunnel, would advance the cause of science, and give a vigorous impulse to the internal improvement of the country. Great results are commonly reached step by step.

General Items.

It has been my continual desire since entering upon this work to learn how to fire several charges at the same time. This I hoped to do of Colonel Tal. P. Schaffner, but his coming upon our work was so long delayed, it being something more than a year after his first brief visit here, that it began to seem hopeless. Last spring, in making a visit to the Bessemer steel-works in Troy, partly in way of business, but more out of curiosity to see and learn something concerning this process of making steel, it was my good fortune to obtain an introduction, through Mr. Holley of the steel-works, to J. J. Revy, of London. Mr. Revy is connected with the gun-cotton works of Loudon, and was acquainted with the most approved methods of simultaneous firing. He very kindly and fully explained to me the process, and gave me a description of the electrical machine and fuses necessary, and also afterwards made a visit to our Tunnel. The Commissioners ordered for me two electric machines, four thousand fuses, and several miles of conducting and connecting wire.

These were several months in transit, and before their arrival Colonel Schaffner came with his material. His machine for exploding was magneto-electrical, and by it and his system of connecting wires it was found impossible to fire more than about five charges at once, and these not simultaneously. This of course was far from satisfactory. Shortly after, the ebonite machines with the Abel fuses ordered for me arrived, and we very soon learned how to use them both, and have been able to fire at once as many as thirty-one charges.

While it is important to save the time which can be saved by this process in firing, and to reduce the risk of accident, and to avoid the smoke made by the burning of the common fuse,

it is much more important to the progress that *simultaneity* of firing be secured. If charges in adjoining holes can be fired as though but *one* charge, then they help each other and much more rock will be torn away. The whole top may be thrown down or the bottom brought up by proper arrangement of holes, and by means of a ring of converging holes, the centre may be dragged out. The passage of the electric spark through *one* system of wires occupies practically no appreciable time, while through several systems it may. If the charges in adjoining holes are fired with the interval of an instant, it may just as well be a week as far as the tearing of the rock is concerned.

The number of fuses obtained was so small that their influence upon progress is hardly appreciable, except possibly at the Central Shaft.

Under the direction of Colonel Schaffner, experiments have been tried at the West Shaft with nitro-glycerin.

The article used was imported from Europe, and much time was consumed in ordering, shipping, and passing it through the custom house.

In these experiments Colonel Schaffner has been eminently successful. No accident has resulted, and indeed there seems to be comparatively little risk if the article is good and ordinary care is taken in its use.

The glycerin will occasion to some persons, if they are exposed to it in a particular manner, a headache for an hour or two, while others are not thus affected. Our men have made very little complaint in this respect, and indeed there has been no difficulty experienced in introducing this *new* and powerful explosive among men who never before have used anything but powder.

It was some time ago demonstrated by experiment, that *double* progress could be made with glycerin over that made with powder, at *less* cost. This is a wonderful achievement, and its effect upon the prospect of this work, in regard to its early completion, at reasonable cost, cannot but be good.

It is true that the experiment was limited to a shorter time by reason of the small supply of electrical fuses and glycerin than could have been wished, and that my views may upon further experience be modified or changed even, but with what infor-

mation I *now* have, there is no room to doubt its fitness for our purpose. It is the testimony of all who have seen our work, including Mr. Revy, George Berkley, of London, C. E., Dr. Ehrhardt, of London, Colonel Schaffner and others familiar with tunnelling, that while our rock is not in general harder to drill than many others, it is most persistently tough. That is, the number of charges we fire, if they could be in granite, or lime, or in any brittle stone, would bring out two or three times more of debris than now. It is therefore necessary that we should have the quickest explosive to get the best result. As preparations of mercury are not to be thought of on account of their danger, we take glycerin as being next to them in power, while it is *comparatively* safe. Whenever its extensive use shall be concluded upon, it will be necessary to secure the services of some scientific person expert in handling it, that some antidote against headache may be discovered, and that the risk may be reduced to the lowest possible point.

Bulk for bulk, which is the only useful comparison to be made here, nitro-glycerin is eight times more powerful than common powder.

During the year my assistants have been William P. Granger, resident at West End and West Shaft, F. W. D. Holbrook at the East End, and W. G. Coolidge at the Central Shaft; and I wish here to express my satisfaction with the manner in which they have performed their duties and my belief in their ability and faithfulness. It is only *through* them that I am able to have the whole work under my eye all the time, and only *by* them is it possible to try the various experiments necessary in the progress of the work, and only *from* them can I get the monthly estimates from the different parts of the work, which will enable me to judge whether any part of the work is less rapidly or economically pushed than any other.

They also act as checks upon the lines and grades of each other, which they are sometimes required to examine, and in which there is great chance for error.

Division of the Work.

As heretofore the different parts of the work are known under the five different names of Deerfield Dam, East End, Central Shaft, West Shaft and West End.

Under West Shaft there will be the subdivision of Supplementary Shaft, and under West End that of Brickyard.

Deerfield Dam and Water-Power.

The following is a table giving the amount of water over the crest of the dam, measured twice a day for the year, so far as it has been practicable to do so.

1865.	Feet. A. M.	Feet. P. M.	1865.	Feet. A. M.	Feet. P. M.
November 1,	2.17	1.67	December 11,	0.64	0.60
" 2,	1.24	1.09	" 12,	0.59	0.62
" 3,	2.34	1.72	" 13,	0.99	1.70
" 4,	1.24	1.24	" 14,	1.32	1.20
" 5,	2.67	2.24	" 15,	0.74	0.66
" 6,	1.41	1.32	" 16,	0.47	0.51
" 7,	1.08	0.86	" 17,	0.42	0.42
" 8,	0.70	0.78	" 18,	0.39	0.30
" 9,	0.66	0.62	" 19,	0.36	0.45
" 10,	0.60	0.54	" 20,	0.57	0.47
" 11,	0.45	0.43	" 21,	0.36	0.39
" 12,	0.41	0.40	" 22,	0.44	0.47
" 13,	0.44	0.46	" 23,	0.55	0.58
" 14,	0.48	0.47	" 24,	0.65	0.72
" 15,	0.50	0.49	" 25,	0.75	0.78
" 16,	0.53	0.55	" 26,	0.73	0.74
" 17,	0.80	0.80	" 27,	0.75	3.10
" 18,	0.79	0.75	" 28,	1.38	1.36
" 19,	0.69	0.75	" 29,	1.00	0.93
" 20,	0.75	0.77	" 30,	0.80	0.65
" 21,	0.69	0.70	" 31,	0.60	0.58
" 22,	1.32	1.49			
" 23,	1.32	1.19	1866.		
" 24,	0.95	0.95	January 1,	0.54	0.55
" 25,	0.85	0.82	" 2,	0.50	0.46
" 26,	0.78	0.74	" 3,	0.42	0.44
" 27,	0.70	0.70	" 4,	0.40	0.38
" 28,	0.70	0.66	" 5,	0.33	0.32
" 29,	0.49	0.47	" 6,	0.50	0.60
" 30,	0.52	0.60	" 31,	–	0.50
December 1,	0.62	0.63	February 1,	0.50	0.47
" 2,	0.51	0.52	" 2,	0.47	0.48
" 3,	0.56	0.56	" 3,	0.50	0.48
" 4,	0.55	0.89	" 4,	0.60	0.52
" 5,	1.34	1.99	" 5,	0.55	0.52
" 6,	1.19	1.03	" 6,	0.72	0.67
" 7,	0.76	0.72	" 7,	0.90	0.40
" 8,	0.56	0.52	" 8,	0.40	0.30
" 9,	0.42	0.48	" 9,	0.35	0.34
" 10,	0.62	0.62	" 10,	0.40	0.35

1866.	Feet. A. M.	Feet. P. M.	1866.	Feet. A. M.	Feet. P. M.
February 11, . .	0.40	0.38	April 4, . .	–	–
" 12, . .	0.52	1.30	" 5, . .	1.30	2.60
" 13, . .	2.20	1.70	" 6, . .	2.00	2.50
" 14, . .	1.10	0.90	" 7, . .	2.40	1.65
" 15, . .	0.85	0.80	" 8, . .	1.30	1.30
" 16, . .	0.60	0.80	" 9, . .	1.25	1.30
" 17, . .	0.60	1.10	" 10, . .	1.00	0.75
" 18, . .	0.50	0.70	" 11, . .	0.70	0.80
" 19, . .	0.50	1.90	" 12, . .	0.90	1.00
" 20, . .	1.90	1.70	" 13, . .	1.40	1.40
" 21, . .	1.30	0.80	" 14, . .	1.85	1.70
" 22, . .	0.90	1.00	" 15, . .	2.40	2.10
" 23, . .	1.05	0.90	" 16, . .	1.80	1.50
" 24, . .	1.20	2.60	" 17, . .	1.30	1.10
" 25, . .	3.10	2.20	" 18, . .	1.10	1.00
" 26, . .	1.20	1.20	" 19, . .	1.30	1.40
" 27, . .	1.05	1.00	" 20, . .	1.50	1.58
" 28, . .	0.85	0.85	" 21, . .	1.48	1.52
March 1, . .	0.70	0.65	" 22, . .	1.30	1.32
" 2, . .	0.60	0.60	" 23, . .	1.18	1.20
" 3, . .	0.70	0.67	" 24, . .	2.12	2.20
" 4, . .	0.60	0.60	" 25, . .	1.55	1.30
" 5, . .	0.50	0.45	" 26, . .	1.20	0.95
" 6, . .	0.50	0.20	" 27, . .	0.85	0.80
" 7, . .	0.15	0.40	" 28, . .	0.70	0.70
" 8, . .	0.45	0.55	" 29, . .	0.70	0.70
" 9, . .	0.40	0.50	" 30, . .	0.68	0.65
" 10, . .	0.60	0.50	May 1, . .	0.60	0.58
" 11, . .	0.50	0.40	" 2, . .	0.55	0.60
" 12, . .	0.40	0.40	" 3, . .	0.57	0.55
" 13, . .	0.90	1.00	" 4, . .	0.52	0.48
" 14, . .	1.20	1.05	" 5, . .	0.48	0.47
" 15, . .	1.10	2.05	" 6, . .	0.42	0.40
" 16, . .	2.20	2.50	" 7, . .	0.40	0.40
" 17, . .	1.80	1.50	" 8, . .	0.37	0.32
" 18, . .	1.00	1.00	" 9, . .	0.31	0.38
" 19, . .	0.80	0.80	" 10, . .	0.51	0.43
" 20, . .	0.60	0.70	" 11, . .	0.43	0.43
" 21, . .	0.75	0.70	" 12, . .	0.41	0.39
" 22, . .	0.60	0.75	" 13, . .	0.37	0.34
" 23, . .	0.50	0.65	" 14, . .	0.70	0.97
" 24, . .	0.60	0.62	" 15, . .	0.72	0.67
" 25, . .	0.50	0.55	" 16, . .	0.57	0.52
" 26, . .	0.45	0.70	" 17, . .	0.72	0.68
" 27, . .	0.90	0.70	" 18, . .	0.62	0.58
" 28, . .	0.60	0.60	" 19, . .	0.52	0.51
" 29, . .	0.70	0.65	" 20, . .	0.47	0.43
" 30, . .	0.55	0.60	" 21, . .	0.40	0.39
" 31, . .	0.65	0.55	" 22, . .	0.36	0.34
April, 1, . .	0.67	0.75	" 23, . .	0.33	0.37
" 2, . .	0.90	0.74	" 24, . .	0.33	0.20
" 3, . .	0.65	0.70	" 25, . .	0.28	0.31

1866.		Feet.	
		A. M.	P. M.
May	26, . .	0.31	0.31
"	27, . .	0.28	0.36
"	28, . .	2.32	2.12
"	29, . .	1.81	1.38
"	30, . .	0.98	0.90
"	31, . .	0.90	0.90
June	1, . .	0.80	0.71
"	2, . .	0.67	0.59
"	3, . .	0.57	0.53
"	4, . .	0.59	1.05
"	5, . .	0.98	0.88
"	6, . .	0.83	0.84
"	7, . .	1.70	1.47
"	8, . .	1.19	1.03
"	9, . .	0.85	0.83
"	10, . .	0.67	0.62
"	11, . .	0.60	0.56
"	12, . .	0.51	0.48
"	13, . .	0.41	0.40
"	14, . .	0·75	0.68
"	15, . .	0.79	0.69
"	16, . .	0.55	0.49
"	17, . .	0.46	0.43
"	18, . .	1.18	2.07
"	19, . .	1.53	1.19
"	20, . .	0.90	0.79
"	21, . .	0.61	0.59
"	22, . .	0.48	0.51
"	23, . .	0.63	0.57
"	24, . .	0.48	0.45
"	25, . .	0.36	0.36
"	26, . .	0.27	0.30
"	27, . .	0.20	0.27
"	28, . .	1.10	0.90
"	29, . .	0.60	0.54
"	30, . .	0.40	0.46
July	1, . .	0.48	0.46
"	2, . .	0.39	0.28
"	3, . .	0.25	0.22
"	4, . .	0.22	0.20
"	5, . .	0.20	0.49
"	6, . .	0.38	0.33
"	7, . .	0.24	0.20
"	8, . .	0.22	0.22
"	9, . .	0.37	0.62
"	10, . .	0.40	0.37
"	11, . .	0.28	0.23
"	12, . .	0.20	0.14
"	13, . .	0.18	0.05
"	14, . .	0.11	0.08
"	15, . .	0.15	0.15
"	16, . .	0.04	–

1866.		Feet.	
		A. M.	P. M.
July	17, . .	0.10	0.25
"	18. . .	0.90	0.95
"	19, . .	1.10	1.00
"	20, . .	1.00	1.00
"	21, . .	0.95	0.85
"	22, . .	1.00	1.00
"	23, . .	1.00	1.45
"	24, . .	1.50	1.45
"	25, . .	1.30	1.05
"	26, . .	1.00	0.95
"	27, . .	0.85	0.55
"	28, . .	0.78	0.95
"	29, . .	1.00	1.00
"	30, . .	0.90	0.90
"	31, . .	0.90	0.80
August	1, . .	0.95	0.70
"	2, . .	0.90	0.75
"	3, . .	0.98	0.70
"	4, . .	0.90	0.80
"	5, . .	1.00	0.95
"	6, . .	0.95	1.00
"	7, . .	1.00	1.10
"	8, . .	1.00	0.95
"	9, . .	1.00	0.95
"	10, . .	1.50	1.40
"	11, . .	1.25	1.20
"	12, . .	1.10	1.05
"	13, . .	1.00	0.95
"	14, . .	0.95	0.95
"	15, . .	0.95	1.40
"	16, . .	1.65	1.50
"	17, . .	1.25	1.70
"	18, . .	1.10	1.00
"	19, . .	1.00	1.00
"	20, . .	1.50	1.10
"	21, . .	1.20	1.10
"	22, . .	1.10	0.90
"	23, . .	1.05	0.90
"	24, . .	1.10	1.10
"	25, . .	1.05	0.95
"	26, . .	0.95	0.90
"	27, . .	1.05	0.80
"	28, . .	0.95	0.80
"	29, . .	0.95	0.80
"	30, . .	0.82	0.70
"	31, . .	0.92	0.78
September	1, . .	0.75	0.62
"	2, . .	0.85	0.85
"	3, . .	0.60	0.45
"	4, . .	1.00	0.98
"	5, . .	0.92	1.00
"	6, . .	1.00	1.00

1866.	Feet. A. M.	Feet. P. M.	1866.	Feet. A. M.	Feet. P. M.
September 7, . .	1.00	1.00	October 5, . .	0.21	0.20
" 8, . .	0.80	1.00	" 6, . .	0.19	0.17
" 9, . .	0.20	0.20	" 7, . .	0.25	0.22
" 10, . .	0.10	0.10	" 8, . .	0.18	0.21
" 11, . .	0.10	0.20	" 9, . .	–	–
" 12, . .	1.00	1.60	" 10, . .	–	–
" 13, . .	1.60	1.00	" 11, . .	–	–
" 14, . .	0.80	0.80	" 12, . .	0.25	0.20
" 15, . .	0.80	0.70	" 13, . .	0.20	0.15
" 16, . .	0.70	0.50	" 14, . .	0.25	0.25
" 17, . .	0.40	0.40	" 15, . .	0.25	0.20
" 18, . .	0.50	0.70	" 16, . .	0.40	0.20
" 19, . .	0.90	1.00	" 17, . .	0.10	0.20
" 20, . .	1.40	1.00	" 18, . .	0.20	0.20
" 21, . .	1.10	1.30	" 19, . .	0.20	0.17
" 22, . .	2.83	1.40	" 20, . .	0.25	0.17
" 23, . .	1.40	1.10	" 21, . .	0.25	0.25
" 24, . .	0.85	0.80	" 22, . .	0.13	0.13
" 25, . .	0.60	0.60	" 23, . .	0.17	0.15
" 26, . .	0.50	0.50	" 24, . .	0.15	0.13
" 27, . .	0.82	0.95	" 25, . .	0.13	0.13
" 28, . .	0.80	0.60	" 26, . .	0.17	0.14
" 29, . .	0.40	0.50	" 27, . .	0.16	0.16
" 30, . .	0.50	0.45	" 28, . .	0.25	0.25
October 1, . .	0.38	0.32	" 29, . .	0.25	0.25
" 2, . .	0.32	0.32	" 30, . .	1.20	8.30
" 3, . .	0.28	0.25	" 31, . .	3.00	2.00
" 4, . .	0.25	0.20			

From July 18 to September 9, temporary and leaky flash-boards, nine inches in height, were on the crest of the dam.

October 9th, 10th and 11th, the pond above the dam was drawn down in order to plank worn places in lower aprons.

The following is a table of rain-fall at the East End :—

January, ...	2.206 inches.
February, ...	4.409 "
March, ...	3.000 "
April, ...	2.129 "
May, ...	4.009 "
June, ...	6.110 "
July, ...	4.713 "
August, ...	4.895 "
September, ...	4.460 "
October, ...	4.932 "

The dam has through the year safely permitted the passage of the river, including the ice freshets of December 27, of 7 feet, and February 24, of 6 feet, and the water freshets of October 30, of $8\frac{8}{10}$ feet, and that of November 16, of 6 feet, which are the principal ones.

The canal, which had during the previous year been somewhat leaky through the coarse diluvial soil of its banks and bed, has now become so tight as to compare favorably with the best canals in New England.

Houses have been built over the head-gates, and the waste-gates and overflow, to prevent the forming of ice about them, and to protect them from mischief-makers.

The masonry of the wheel-house has been extended only so far as necessary to cover the third wheel-pit, before done, and such machinery as might be connected with it, and to permit the moving forward of the canal bulkhead so far as to allow the water to pass to the third wheel.

It has been said that the cost of the wheel-house has been much more than it should have been.

It having been determined to build it, I think its cost can be shown to be not greater than necessary.

The house was located in the only place where it would not be necessary to cut the whole width of the house and canal into a very high bank. It was at the foot of an old, extensive slide.

Upon making the necessary excavations, it was found that the bottom was soft clay, and, very much to our alarm, that the bottom was rising, and that the avalanche was on the move. It therefore became necessary, in connection with the fact that the water-level of the canal back of the house was to be 30 feet higher than the river and front, to build *heavy* masonry. The back wall was made 17 feet thick at the bottom, the whole height of the wall being over 40 feet.

It should further be considered that it became necessary to build with the stone from the Tunnel, because none better could be reasonably obtained. The masonry is therefore simply a conglomerate of junks of stone; but, for want of a natural bond, it must have an artificial one, and this could only be obtained by the use of cement in large quantities, and at great cost, because so far from a railroad. The window and door-

jambs were made from such stone, at great cost for labor, while the caps and sills came from over the mountain.

The house has not moved, or it would indicate it in the derangement of the machinery at work therein.

EAST END.

Work here has only been interrupted by a refusal of the men to work from May 1 to May 8, because their demand for increase of pay was not complied with.

The progress made monthly in the heading is shown in the following table:—

DATE.	Distance from Portal.	Progress.
November 1, 1865,	2,839.0 feet.	
December 1, "	2,904.9 "	65.0 feet.
January 1, 1866,	2,950.5 "	46.5 "
February 1, "	3,005.0 "	54.5 "
March 1, "	3,052.0 "	47.0 "
April 1, "	3,115.0 "	63.0 "
May 1, "	3,176.5 "	61.5 "
June 1, "	3,227.0 "	50.5 "
June 8, "	3,239.5 "	12.5 "
Changed from Hand to Machine Drilling.		
June 14, 1866,	3,239.5 "	
July 1, "	3,253.5 "	14.0 "
August 1, "	3,301.5 "	48.0 "
September 1, "	3,356.0 "	54.5 "
October 1, "	3,394.5 "	38.5 "
November 1, "	3,431.0 "	36.5 "
Total progress for the year,		592.0 feet.

The heading was driven by manual labor until June 8, when it was suspended to prepare for introducing automatic pneumatic drills.

These began their work on the 14th of June. The heading enlargement has been carried to 2,566 feet west of Portal.

From November 1, 1865, to June 8, 1866, there were expended in the East End heading,—

Days of labor, including foreman,	5,476.05
Drills dulled,	112,489.
Inches of hole drilled,	255,769.
Holes made,	9,828.
Pounds of powder used,	6,563.
Feet of fuse used,	30,202.
Pounds of candles used,	2,605.75
Feet of progress made,	400.5
Cubic yards of rock removed,	1,517.3

This will give for one day's labor of one man,—

Drills dulled,	20.540
Inches of hole drilled,	46.703
Holes made,	1.795
Pounds of powder used,	1.198
Feet of fuse used,	5.515
Pounds of candles used,	0.476
Feet of progress made,	0.073
Cubic yards of rock removed,	0.277

Or one foot of advancement requires the expenditure of,—

Days' labor of one man,	13.674
Drills dulled,	280.871
Inches of hole,	638.624
Holes,	24.539
Pounds of powder,	16.387
Feet of fuse,	75.410
Pounds of candles,	6.506
Cubic yards of rock removed,	3.788

We also find that the holes have an average depth of 26.025 inches, that each drill-bit cuts 2.274 inches of hole, and that each hole consumes 0.66779 pounds of powder and 3.0730 feet of fuse. The holes are $1\frac{3}{8}$ inches in diameter.

From June 14, 1866, to November 1, 1866, there were expended, under the machine system, in the East End heading,—

Days of labor, including foremen,	4,350.05
Number of machines sent out,	979.
Drills dulled,	9,336.
Inches of hole drilled,	161,504.
Holes made,	5,229.
Pounds of powder used,	6,313.
Feet of fuse used,	21,951.
Pounds of candles used,	2,267.67
Feet of progress made,	191.5
Cubic yards of rock removed,	925.9

This will give for one day's labor of one man,—

Drilling machines broken down,	0.225
Drills dulled,	2.146
Inches of hole drilled	37.123
Holes made,	1.202
Pounds of powder used,	1.451
Feet of fuse used,	5.046
Pounds of candles used,	0.521
Feet of progress made,	0.044
Cubic yards of rock removed,	0.213

Or one foot of advancement requires the expenditure of,—

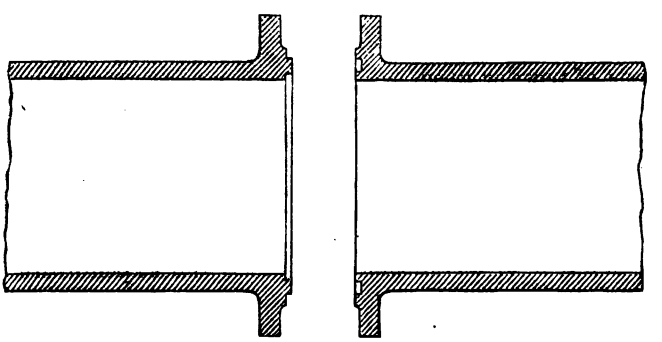
Days' labor of one man,	22.718
Number drilling machines working until broken,	5.112
Drills dulled,	48.752
Inches of hole,	843.363
Holes,	27.305
Pounds of powder	32.966
Feet of fuse,	114.626
Pounds of candles,	11.842
Cubic yards of rock removed,	4.835

We also deduce from the above that the holes have an average depth of 30.886 inches, that each drill-bit cuts 17.299

inches of hole, that each drilling machine, while in working order cut 164.968 inches of hole, or 5.341 holes, and that each hole consumes 1.207 pounds of powder and 4.178 feet of fuse. The holes are $1\frac{5}{8}$ to $1\frac{6}{8}$ inches in diameter and perfectly round.

The wooden culvert to contain the pipes and carry away the water has been laid as far as the heading enlargement will permit. From the wheel-house, the 8-inch iron pipe to convey the pneumatic power, and the 12-inch iron pipe for additional ventilating air, have been laid, also from the Portal the 3-inch iron pipe for water.

The joints in these various sized pipes are similarly made, there being a recess $\frac{3}{4}$ inch wide and $\frac{3}{16}$ inch deep, turned in one flange, while upon the other is turned a corresponding follower or projection. In this recess, and before the follower, is put a rubber packing-ring of pure gum, $\frac{3}{4}$ inch wide and $\frac{1}{8}$ inch thick. This makes a remarkably tight joint, and can be understood more easily by reference to the following diagram:—



The blacksmith's shop is near the line of air-pipes, and the fires in its forges are blown by air taken from the 8-inch pipe. The air from this pipe is also to be used for running a power hammer, now under construction by Lyman Kingsley.

Under the supposition that coal-gas was to be made outside the Tunnel for use in the heading, at the enlargement, in the blacksmith's shop and at the wheel-house, a gas-pipe has been laid in the Tunnel culvert with the other three pipes. But should the present experiment in the use of naptha gas prove successful, it will be of no use.

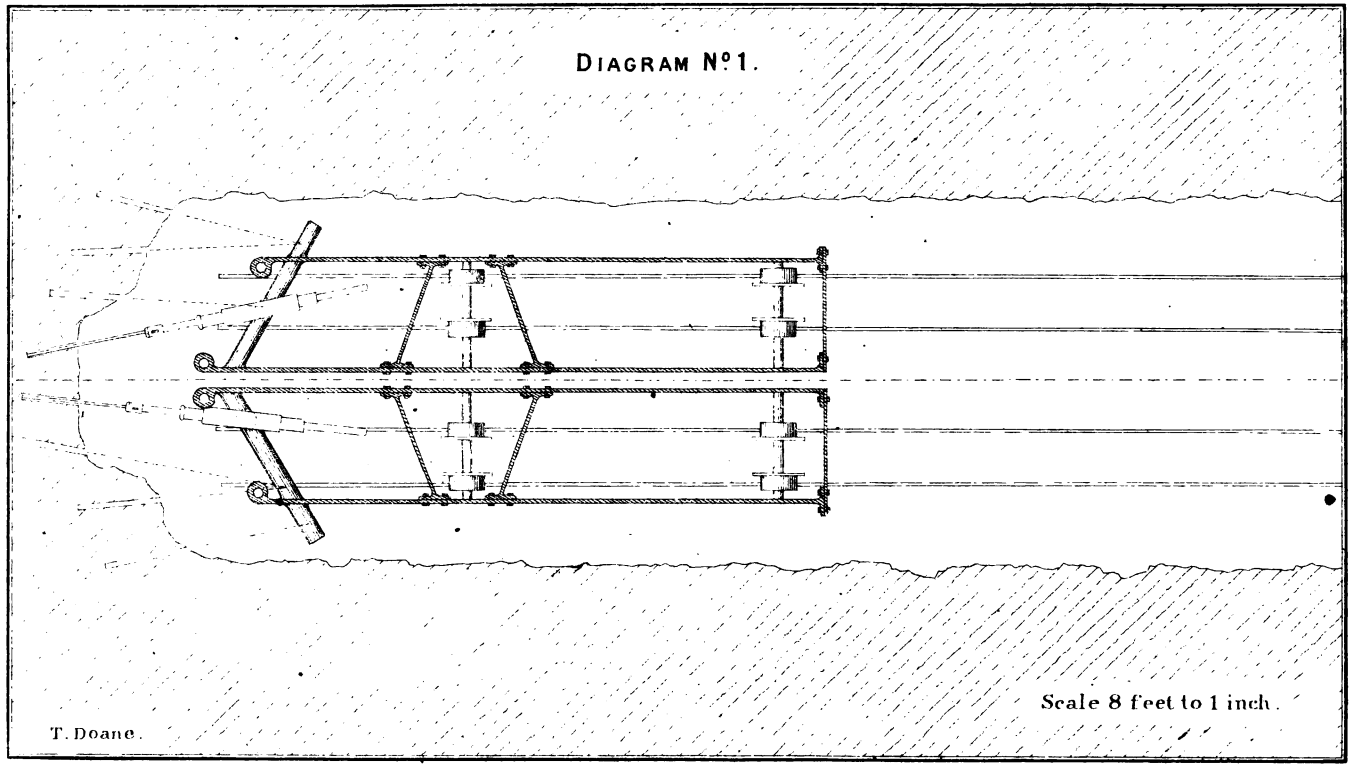


DIAGRAM Nº 1.
Scale 8 feet to 1 inch.
T. Doane.

When a heading is driven by hand, it is possible and usual to locate each hole in such a place, and drive it in such a direction, as will enable it to get the most rock. That is, the holes can be arranged to suit the form of the heading as left by the previous blast. The fact that machine labor cannot do this as well has been one great argument against its use.

To meet the above objection to machine drilling, there being nothing in the machine drills themselves to prevent it, the carriage spoken of in my last report was devised. Diagram No. 1 will explain its shape in plan as adapted to the form of the heading.

It is found in practice that a hole can be put in almost any place and direction by means of these machines and carriages. The carriages may not be perfect in every respect, but it is enough to say of them that they have met all the demands made upon them. They will hold a machine in place to drill a hole wherever wanted, for it has not been necessary to make a hand hole since the machines went in; they can be taken out beyond reach of the blasts, or brought in again in a few minutes by the men in the heading, and they have not in any respect shown a want of strength, nor has anything been spent in repairs upon them.

It will be seen by reference to the table, that with machine drilling, a progress about equal to that by hand drilling was very soon reached, and this was done by the old gangs, with the addition to each gang at first of two mechanics, now reduced to one.

This was when the machines were new, and when there was a larger supply on hand than there has since been, which must be our excuse for not maintaining greater progress. Had a sufficient supply of machines been provided, there can be little doubt that very much greater progress would have been attained.

The following table gives the average times occupied under the machine-drilling system in the various operations. The blasting has been done once in eight hours, and the averages are made up from data kept through the whole time.

1866.	Removing Rock.	Preparing to Drill.	Machines Drilling.	Loading and Blasting.
July, . . .	1 hr. 08 min.	0 hr. 32 min.	5 hr. 07 min.	1 hr. 13 min.
August, . .	1 08	0 30	5 06	1 16
September, . .	1 03	0 13	5 31	1 23
October, . .	0 54	0 10	5 57	0 59

Whenever the machines shall be able to make the necessary number of holes, so that blasting can advantageously be oftener done, a change will be made to blasting once in six hours, or to blasting twice in each shift.

Central Shaft.

This part of the work has been continuously driven, except from the 6th of May to the 1st of August, when the new hoisting machinery was being put in place.

The following table gives progress in sinking during the year covered by this Report:—

DATE.	Distance Down.	Progress.
November 1, 1865, ...	200.8 feet.	–
December 1, 1866, ...	220.1 "	19.3 feet.
January 1, 1866, ...	232.5 "	12.4 "
February 1, "	250.7 "	18.2 "
March 1, "	264.0 "	13.3 "
April 1, "	280.9 "	16.9 "
May 1, "	297.1 "	16.2 "
May 6, "	300.5 "	3.4 "
Stopped to put in new hoisting apparatus, .	–	–
August 1, 1866, ...	300.5 "	–
September 1, "	311.9 "	11.4 "
October 1, "	331.1 "	19.2 "
November 1, "	354.0 "	22.9 "
Progress for the year, ...	–	153.2

From November 1, 1865 to October 6, 1866, the common fuse or slow match was used in firing the charges, and generally, out of eight or nine holes to a shift, one or two would be lost through the extinguishment of the lighting candle or the fuse. Since October 6, the Abel fuse has been used, and the firing is done by electricity from the office above ground, and it is very rare to lose a hole. This system relieves the men from all risk in firing the charges, which had come to be very considerable; they can at once return below without any fear that a charge hangs fire and the smoke is very light, because that resulting from burnt fuse is entirely avoided.

From November 1, 1865 to October 6, 1866 there were expended in sinking this shaft,—

Days of labor, including foremen,	7,674.5
Drills dulled,	41,056.
Inches of hole drilled,	136,876.5
Holes made,	3,272.
Pounds of powder used,	6,010.75
Feet of fuse used,	17,401.5
Pounds of candles used,	126.
Quarts of oil used,	1,087.75
Feet of progress made,	134.2
Cubic yards of rock removed,	1,745.9

This will give for one day's labor of one man,—

Drills dulled,	5.350
Inches of holes drilled,	17.835
Holes made,	0.426
Pounds of powder used,	0.783
Feet of fuse used,	2.267
Pounds of candles used,	0.016
Quarts of oil used,	0.142
Feet of progress made,	0.017
Cubic yards of rock removed,	0.227

Or one foot of progress requires the expenditure of,—

Days' labor of one man,	57.187
Drills dulled,	305.931

Inches of hole,	1,019.944
Holes,	24.382
Pounds of powder,	44.789
Feet of fuse,	129.668
Pounds of candles,	0.939
Quarts of oil used,	8.105
Cubic yards of rock removed,	13.000

There were 27,460.5 inches of $2\frac{1}{2}$-inch holes, 109,171.5 inches of 2-inch holes, and 244.5 inches of $1\frac{1}{2}$-inch holes.

We also find that the holes have an average depth of 41.832 inches, that each drill-bit cuts 3.334 inches of hole, and that each hole consumes 1.837 pounds of powder and 5.318 feet of fuse.

From October 6, 1866 to November 1, 1866, there were expended in sinking this shaft,—

Days of labor, including foremen,	901.75
Drills dulled,	4,280.
Inches of hole drilled,	19,486.5
Holes made,	437.
Pounds of powder used,	731.5
Abel's fuses,	451.
Quarts of oil,	134.25
Feet of progress made,	19.
Cubic yards of rock removed,	247.

This will give for one day's labor of one man,—

Drills dulled,	4.746
Inches of hole drilled,	21.610
Holes made,	0.485
Pounds of powder used,	0.811
Abel's fuses used,	0.500
Quarts of oil used,	0.149
Feet of progress made,	0.022
Cubic yards of rock removed,	0.274

Or one foot of progress requires the expenditure of,—

Days' labor of one man,	47.461
Drills dulled,	225.263
Inches of hole,	1,025.605
Holes,	23.000
Pounds of powder,	38.500
Abel's fuses,	23.737
Quarts of oil,	7.066
Cubic yards of rock removed,	13.000

There were 11,291 inches of 2-inch holes, and 8,195.5 inches of 2½-inch holes.

We also find from the above that the holes have an average depth of 44.592 inches, that each drill-bit cuts 4.553 inches of hole, and that each hole consumes 1.674 pounds of powder and 1.032 Abel's fuses.

No machine drills have been used here, as those intended for this purpose have been converted into horizontal ones for the East End. The air compressors, reservoirs, and pipes, are, however, all in place and ready for work.

The amount of water in the shaft is slight, only about 11 gallons per minute.

The following is a table showing the monthly consumption of fuel, oil, &c., in the engine-house.

DATE.	Number cords of Wood.	No. galls. Sperm Oil.	No. pounds Tallow.	No. pounds Waste.	No. pounds Tar.	No. tubs Stone raised.	No. tubs Water raised.	No. tubs with Men or Tools.
November, 1865,	97.7	11	5	14	2	854	1,997	457
December, "	125.9	11¼	5¾	13	3	620	3,040	458
January, 1866,	163.8	18¾	11	10¼	2	885	2,975	458
February, "	153.5	14¾	4	13¼	3	550	2,874	421
March, "	145.4	13½	2½	21½	–	783	3,080	386
April, "	132.0	11	2	22¾	–	639	2,874	381
May, "	113.3	13¾	8	16¼	–	143	2,055	211
June, "	99.1	11½	6	14	–	–	–	–
July, "	101.7	14¾	9½	13½	–	–	–	–
August, "	99.4	17½	8	20¼	11	464	1,150	364
September, "	87.5	15¼	10	14¾	2	829	1,035	444
October, "	100.1	14½	8½	9½	–	882	1,015	468
Totals,	1,418.4	167½	80¼	183	23	6,649	22,095	4,048

West Shaft.

The work at this point has been uninterrupted during the year.

The progress made monthly in the headings and their enlargement, is shown in the following table :—

West Heading.

DATE.	Distance from Shaft.	Progress.
August 2, 1865, stopped, ...	280.8 feet.	–
September 19, 1866, begun, ...	280.8 "	–
October 3, 1866, stopped, ...	298.0 "	18.2 feet.

Heading Enlargement.

May 11, 1866, begun, ...	4.0 feet.	–
July 1, 1866, ...	100.0 "	96.0 feet.
August 1, 1866, ...	160.0 "	60.0 "
September 1, 1866, ...	225.0 "	65.0 "
October 3, 1866, stopped, ...	298.0 "	73.0 "
Total progress, ...	–	294.0 feet.

EAST HEADING.

HEADING.			ENLARGEMENT.		
DATE.	Distance from Shaft.	Progress.	DATE.	Distance from Shaft.	Progress.
November 1, 1865, .	367.5	–			
December 1, 1865, .	414.4	46.9			
January 1, 1866, .	459.4	45.0			
February 1, 1866, .	503.0	43.6			
March 1, 1866, .	546.5	43.5			
April 1, 1866, . .	584.8	38.3	April 1, 1866, .	372.4	–
May 1, 1866, . .	623.3	38.5	May 1, 1866, . .	418.4	46.0
June 1, 1866, . .	682.1	58.8	June 1, 1866, .	492.7	74.3
July 1, 1866, . .	746.1	64.0	July 1, 1866, . .	568.7	76.0
August 1, 1866, .	810.5	64.4	August 1, 1866, .	645.7	77.0
September 1, 1866, .	871.4	60.9	September 1, 1866,	750.1	104.4
October 1, 1866, .	945.4	74.0	October 1, 1866, .	844.3	94.2
November 1, 1866, .	1,004.2	58.8	November 1, 1866,	950.0	105.7
Total progress,	–	636.7			

The enlargement of the west heading has brought it to a size 15 feet wide and 10.5 feet high, except that the bottom has not been taken to grade. This is because the grade must, for the present, descend towards the shaft in order to vent the water, while the final grade must ascend towards the shaft. There remains about two feet of bottom to take up near the shaft and three feet at the west heading, which will be accomplished by the time the pumping engines are ready for the supplementary shaft, in order that all the water of the shaft may run to it.

The west heading has reached better rock than that in which it was left on the 2d of August, 1865, and as soon as sufficient pumps are ready, it will be driven again towards the West End, with almost a certainty of going through tolerably good rock for about one thousand feet, and perhaps more.

The east heading is enlarged to its full size of 15 feet wide by 10.5 feet high. In this heading, the experiments with nitro-glycerin were tried by Colonel Schaffner. Those in the

enlargement were upon the 8th, 9th and 10th of August, and those in the heading upon the 8th, 9th and 10th of October.

The enlargement was driven about *thrice* as rapidly as under the use of common powder, at a saving of $3.64 per cubic yard of rock removed, while the heading was driven about *twice* as rapidly, at a saving of $10.20 per cubic yard. These results have been heretofore given more in detail in my letter to you.

During the past year, in the east heading there have been expended,—

Days of labor, including foremen,	10,101.
Drills dulled,	188,505.
Inches of hole drilled,	447,450.
Holes made,	18,186.
Pounds of powder used,	9,704.
Feet of fuse,	40,896.
Pounds of candles,	3,447.
Feet of progress made,	636.7
Cubic yards of rock removed,	2,358.

This will give for one day's labor of one man,—

Drills dulled,	18.662
Inches of hole drilled,	44.298
Holes made,	1.800
Pounds of powder used,	0.961
Feet of fuse used,	4.049
Pounds of candle used,	0.342
Feet of progress made,	0.063
Cubic yards of rock removed,	0.233

Or one foot of advancement requires the expenditure of—

Days' labor of one man,	15.865
Drills dulled,	296.066
Inches of holes,	702.764
Holes,	28.563
Pounds of powder,	15.241
Feet of fuse,	64.231
Pounds of candles,	5.414
Cubic yards rock removed,	3.703

We also find that the holes have an average depth of 24.604 inches; that each drill-bit cuts 2.374 inches of hole, and that each hole consumes 0.533 pounds of powder and 2.249 feet of fuse. The holes are $1\frac{3}{8}$ inches in diameter, and being hand holes, not round, but rather triangular.

The hoisting apparatus has worked during the year most satisfactorily. The water has gradually increased until, at the end of the year, it amounted to 97 gallons per minute, or about as much as the pumps, running at their natural speed, could deliver.

The three men who had been lying in Lenox jail awaiting trial by a higher court, for burning the West Shaft buildings in February, 1865, were released in January, 1866, the grand jury failing to indict them.

The following is a table showing the monthly consumption of fuel, oil, &c., in the engine-house:—

DATE.	No. tons Coal.	No. cords Wood.	No. gallons Oil, (Sperm.)	No. gals. Kerosene.	No. of pounds of Waste.	No. Cages raised.	No. cars of Stone raised.
November, 1865, .	57.832	–	$20\frac{1}{4}$	$7\frac{3}{4}$	2	2,702	1,516
December, " .	40.450	29.9	$18\frac{3}{4}$	$8\frac{1}{2}$	$2\frac{1}{2}$	2,468	1,052
January, 1866, .	–	106.	$20\frac{3}{4}$	$8\frac{1}{2}$	$1\frac{1}{2}$	2,175	1,106
February, " .	–	91.4	$16\frac{1}{2}$	$7\frac{1}{2}$	$2\frac{1}{2}$	2,282	880
March, " .	35.250	63.6	$17\frac{1}{2}$	8	2	2,457	1,119
April, " .	57.025	24.9	14	5	$1\frac{1}{2}$	2,199	1,165
May, " .	50.350	12.7	$12\frac{1}{2}$	$4\frac{1}{2}$	4	2,686	1,512
June, " .	70.985	–	14	$8\frac{1}{2}$	$8\frac{1}{4}$	3,089	1,820
July, " .	45.550	31.0	$14\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	2,899	1,816
August, " .	–	67.1	18	6	4	3,291	2,051
September, " .	–	60.4	$15\frac{1}{4}$	9	$5\frac{1}{2}$	3,352	2,143
October, " .	–	66.0	$16\frac{1}{2}$	7	4	3,135	1,945
Totals, . . .	357.442	553.0	$148\frac{1}{2}$	$78\frac{3}{4}$	$40\frac{1}{4}$	32,735	18,125

West Supplementary Shaft.

Under the head, Line, the necessity for this shaft in order to verify the line was stated. It would have been more satisfactory in an engineering point of view, could it have been located further from the West Shaft. But when it was begun it was very uncertain whether the west heading could be driven further without drowning the shaft workings. It must, therefore, in order to be available, open into the west heading already driven. Nor was it desirable to have it penetrate through the bad rock, in which the heading had to be stopped. It was therefore located so that it would probably come down through good rock, in order to avoid a great flow of water, and the necessity for timbering.

It was thought to be very difficult to bore a hole of only a few inches in diameter so nearly vertical as to answer the purpose for line. And upon conferring with miners, it was found that a shaft of the size decided upon, could be sunk at very little more cost than a smaller one.

It was also found that something must very shortly be done at the West Shaft to increase the pumping capacity. There was not room for larger pumps in the West Shaft, except by taking out the present one, which would for awhile occasion a suspension of the work.

The West Shaft is 316 feet deep; the Supplementary, 277 feet; and by running a small drift into it from a north-westerly direction, a further saving of forty-one feet could be effected. This would reduce the lift of water about eighty feet, or to 236 feet, thus saving one-fourth of the expense of pumping the water for several years, enough probably to pay the entire cost of the new shaft. It was therefore determined to make the shaft six feet by thirteen feet in the clear, the last dimension being at right angles to the Tunnel line. By putting a foot timber in the middle of the shaft, it is divided into two parts, six feet by six feet each. In each of these a pump could be put large enough to lift all the water which could reasonably be expected, and then a reserve pump would be constantly in readiness for a breakdown, or a sudden large influx of water.

The small drift has been run into this shaft and was completed April 22, 1866. It is six feet high, four feet wide at bottom, and two feet at top. It is 101.5 feet long, 72.5 feet

having been in earth which required timbering. It cost $698.50 under contract for labor. The shaft is being sunk by contract, at a cost for labor of from $40 to $60 per foot.

It is being driven both from above down, and from below up, and the progress has been as follows.

The whole depth is to be 277 feet.

From Above down.			From Below up.		
DATE.	Distance down.	Progress.	DATE.	Distance up.	Progress.
	Feet.	Feet.		Feet.	Feet.
December 11, 1865, .	–	–			
January 1, 1866, . .	27.0	27.0			
February 1, 1866, . .	31.0	4.0			
March 1, 1866, . .	65.0	34.0			
April 1, 1866, . .	89.0	24.0			
May 1, 1866, . . .	101.0	12.0			
June 1, 1866, . .	116.5	15.5			
July 1, 1866, . . .	135.0	18.5			
August 1, 1866, . .	151.0	16.0			
September 1, 1866, .	160.0	9.0	September 19, 1866, .	13	–
October 1, 1866, . .	169.0	9.0	October 1, 1866, . .	16	3
November 1, 1866, .	177.5	8.5	November 1, 1866, .	36	20
Progress down, .	–	177.5	Progress up, . .	–	23

It is expected that this shaft will be completed in February next. The charges are being fired by electricity to expedite the work. The quantity of water now being pumped is thirty gallons a minute.

West End.

Under this head in a former report, was a table giving the details concerning the wells or test pits which were being sunk, in order to ascertain the nature of the material. This work has been completed, and the table is again introduced with the blanks filled.

Wells or Test Pits.	No. 1.	No. 2.	No. 3.	No. 4.
Distance from West Shaft—feet, .	2,091.5	1,976.5	1,713.2	924.2
Surface above sub-grade, " .	79.5	117.9	134.0	215.0
Depth of well, " .	38.0	51.0	67.0	103.3
Depth of boring below well, " .	43.5	50.0	68.3	–
Reaching a point above or below sub-grade, ...	—2.0	+16.0	—1.3	+101.7
Top of rotten rock below surface, .	13.0	46.0	67.0	None.
" " " above grade, .	66.5	71.0	67.0	None.
" solid " below surface, .	None.	None.	None.	77.0
" " " above sub-grade, .	None.	None.	None.	138.0

The result of these examinations is most encouraging. At Well No. 3 the borings came from such great depth that the character of the material could not certainly be ascertained. It seemed very much closer, harder and dryer than the rotten rock passed through in Wells No 1 and 2; and several strata were passed through that required drilling, the boring tools not being able to penetrate them.

The material brought up was finely pulverized, and on comparison with powdered stone from Well No. 4, proved to be quite similar.

Well No. 4, was begun of large size,—10 feet internal diameter,—and reached the rock 77 feet down with a diameter of about 8 feet. It is located in the hollow west of the West Shaft, where bad material would be more likely to occur than at any other point between the West End and West Shaft, and where there was every probability of large quantities of water.

It was made large with the hope that, everything proving favorable, it might be sunk to grade, and used as a shaft. Much troublesome quicksand was passed through in going down 52 feet, when a tight, hard pan was reached, which continued for a distance of 25 feet, when rock was reached. This proved to be scienitic in character, and hard, though cut through in various directions by seams.

There was very little trouble experienced in sinking it to a further depth of 26 feet, when a large sand seam was struck.

This discharged so much water, that it was beyond our then ability to free the well, and it was abandoned temporarily, perhaps the main object of the well having been attained.

This is not conclusive proof, but it leads to the presumption that the west heading of the West Shaft can easily be driven to this point, and, judging from the configuration of the ground still farther west and the developments of Well No. 3, for a much greater distance. It will be necessary, however, to provide ample means for pumping beforehand.

These facts put a much more favorable aspect upon this part of the work, than could presumptively be done in the last report.

In the middle of January, the West End heading was resumed again, and was driven with very tolerable success, passing through 30 or 40 feet of hard rock to a point 2,128.5 feet from the West Shaft.

About this time, a contract was made by the Commissioners with B. N. Farren to undertake this work, and the further prosecution of it by the State was suspended. This contract provides for the arching of 174 lineal feet west of the point where the Tunnel passes beneath ground, and for building at least 200 feet of Tunnel east of this point, before the 30th of June, 1867.

The following table gives monthly progress of completed Tunnel to November 1, 1866:—

DATE.	Distance from Ins. Pier.	Distance from West Shaft.	Progress.
Aug. 9, 1866, ...	68.5 feet.	2,378.5 feet.	
Sept. 1, "	100.5 "	2,346.5 "	32.0 feet.
Oct. 1, "	164.0 "	2,283.0 "	63.5 "
Nov. 1, "	200.0 "	2,247.0 "	36.0 "
Progress to Nov. 1, 1866, ...			131.5 "

Since that time, the whole of the 174 feet has been completed, and the tunnel has passed beneath ground.

It has been found that the heading driven by the State had so far dried the material through which the 174 feet passes,

that it was comparatively easy to put in the masonry. Acting upon this experience, Mr. Farren has been permitted to drive a small heading on each side of the Tunnel and some distance outside of its section, in order to drain away the water, and make it possible to push on the Tunnel by the usual process of timbering.

The southerly one is already 20 feet in advance of the point to which he is under contract to build, and the northerly one is well on. They have reached dryer ground than most of that through which they have passed; and it seems advisable to push them on to reach a material through which tunnelling can be done without any question, so that all may feel that this great apparent obstacle to the completion of the Tunnel has been surmounted.

Diagram No. 2 gives the form and size of masonry through the 174 feet already built. A round Tunnel was recommended in the former report, because there was then a chance that the rotten rock reached to the West Shaft, and that an invert would be required for nearly all the distance.

But the information afterwards acquired from the test wells, made it probable that it did not extend beyond a few hundred feet. In order therefore to secure more width at the grade line, and make it conform more nearly to the rock section, the form was modified as shown in the diagram.

Afterwards, under a suggestion from George Berkley, C. E., who was familiar with workings in the London clay, the form was still further modified, and that part east of the 174 feet, or beneath ground will be of the shape indicated in Diagram No. 3.

This masonry is built of brick, and through the 174 feet it is from five to eight courses or rings in thickness, increasing towards the east; eight rings give a thickness of 32 inches.

The large expense heretofore incurred on this part of the work, brought it at length into a state in which it seemed best to begin full size tunnel and line it with masonry.

As before remarked, the removal of the quicksand from overhead, the making and maintaining of surface ditches, and the driving of the heading, had so far *restored the morals* of the rotten rock, by taking away the water, that the contractor found it comparatively easy to do his work. He also found

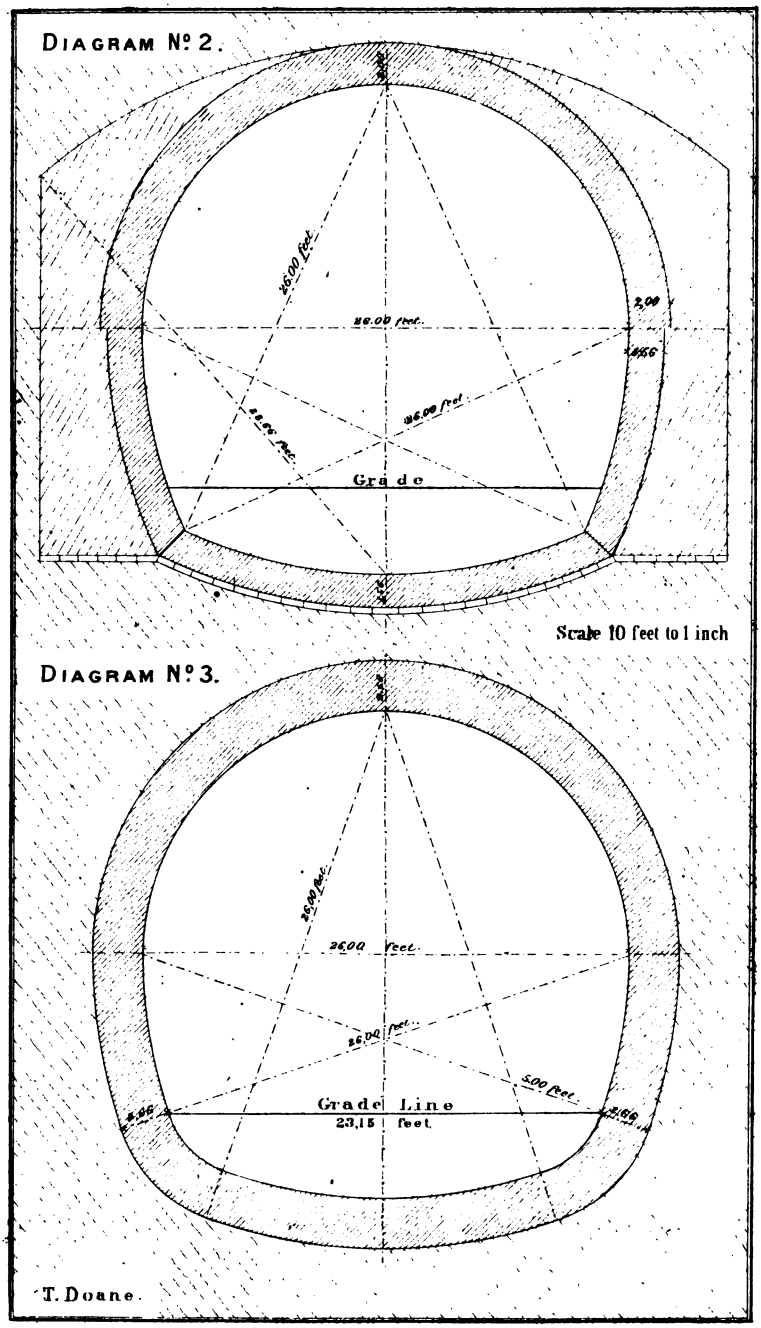


DIAGRAM Nº 2.
26.00 feet.
26.00 feet.
2.00
4.56
26.00 feet.
26.00 feet.
Grade
Scale 10 feet to 1 inch
DIAGRAM Nº 3.
26.00 feet.
26.00 feet.
26.00 feet.
5.00 feet.
Grade Line
23.15 feet.
T. Doane.

tracks, roads, buildings, &c., ready for his use, and the Commissioners, under the contract furnish to him at about cost price, all the brick, timber, lumber, cars, &c., that he needs, so that his time and energy can be devoted exclusively to driving on the work.

Brickyard.

As stated in my former report, land has been bought which furnishes both clay and sand for brick-making. There is probably a superabundance of clay for tunnel purposes, but the sand is in limited quantity.

The clay proves to be of most excellent quality, and the freshly moulded brick have endured both heavy showers and severe frosts excellently well.

At considerable expense, because of the roughness of the ground, a brickyard has been graded near the West End. It is 300 feet long and 120 feet wide, including the kiln shed. It is furnished with four mixing and moulding machines, made by Mr. George F. Blake of Boston, which are driven by a 20-horse engine.

The machines were set up and operated through the season under the direction of A. H. Keay, of Boston, while the burning has been under the more especial care of B. F. Hathaway, of North Adams. The clay and sand have been mixed, except those of the first kiln, in the proportion of 2 of clay to 1 of sand, care being taken to select clay free from loam and stones, and sand coarse and clean. No coal dust has been used in the composition of the brick.

The moulding of brick commenced on the 26th of June and ended on the 24th of October.

The following table is a record of number of kilns burnt, number of bricks, and dates of burning.

No. of Kiln.	No. of Bricks in.	Begun Burning.	Ended Burning.
1	150,000	July 12, 1866, . .	July 21, 1866.
2	230,000	August 2, 1866, . .	August 9, 1866.
3	350,000	August 22, 1866, . .	August 29, 1866.
4	330,000	October 1, 1866, . .	October 9, 1866.
5	610,000	November 2, 1866, .	November 10, 1866.
	1,670,000		

The moulds measure $8\frac{11}{16}$ by 4 by $2\frac{1}{2}$ inches, or $88\frac{1}{2}$ cubic inches.

The bricks measure from $7\frac{7}{10}$ by $2\frac{}{4}$ to $2\frac{3}{10}$ by $3\frac{4}{10}$ to $3\frac{1}{2}$ inches, or $61\frac{98}{100}$ cubic inches, and weigh from $3\frac{3}{4}$ to $3\frac{15}{16}$ pounds each.

About 80 per cent. of the brick are sufficiently hard for lining the Tunnel. They prove to be of very superior quality, being tough, solid and of good shape. Their power to resist crushing has not been tested. Probably a somewhat larger brick will be made next season, and the admixture of a larger proportion of sand may make as good a brick, that will shrink less. Enough bricks are on hand, it is thought, to last till next brick season. This part of the work is now in a state of preparation to be operated under contract.

The cost of brickyard is included under West End expenses.

Expenses.

The following is a statistical account of expenses from the re-opening of the work in 1863 to November 1, 1865.

The first column gives the expenses to November 1, 1865; the second column gives the total expenses to November 1, 1866; the third column gives the expenses for one year from November 1, 1865 to November 1, 1866:—

	First.	Second.	Third.
Engineer'g, Superin., &c.,	$55,999 90	$84,840 48	$24,840 58
Deerfield Dam, . .	125,919 74	127,982 80	2,063 06
Excav. and Masonry East End Dam, . . .	12,535 86	12,802 46	266 60
Wheel-pits and House, .	45,878 09	70,723 23	24,845 14
Gates and Overflow, .	9,419 73	9,986 26	566 53
Race or Canal, . .	21,353 03	23,417 54	2,064 51
East End Enlargement, .	80,317 19	80,317 10	–
E. End Head., Hand Lab.	32,425 88	103,731 45	39,237 09
" " " Mach. "	–	–	32,068 48
" " Head. Enlargem't,	12,602 68	17,559 46	4,956 78
Central Shaft, . . .	85,525 58	144,423 75	58,898 17
West Shaft, . . .	75,778 60	179,041 69	103,263 09
West Approach, . .	134,794 62	247,900 75	113,106 13
Building East End, . .	27,851 65	31,688 99	3,837 34
". Central Shaft, .	9,620 43	12,026 83	2,406 40
" West Shaft and West End, .	33,076 42	40,010 13	6,933 71
Building General, . .	7,694 39	9,537 37	1,842 98
Machin'ry Deerfield Dam,	10,297 92	10,820 93	523 01
Machinery East End, .	20,537 79	87,032 38	66,494 59
" Central Shaft,	22,472 93	51,364 01	28,891 08
" West Shaft,	36,388 62	57,111 73	20,723 11
" " End, .	36 62	539 89	503 27
" General, .	18,927 68	62,600 76	43,673 08
Land and Right of Way,	8,613 84	17,513 21	8,899 37
Miscellaneous, . . .	556 62	*Trans. to Troy & Greenf'd R. R.*	
	$892,625 72	$1,482,973 20	$590,904 10

Engineering and Superintendence includes, besides engineering proper, the cost of superintendence, the cost of all engineering instruments, the expenses of cashier's office, the barn account of engineers and superintendents, some expenses of Commissioners and Consulting Engineer, and the cost of the four instrumental station-houses.

The following is a statistical account of expenses for one year from November 1, 1865, to November 1, 1866.

The first column gives the total expenses of all sorts, under their various heads.

The second column gives the amounts, by estimation, which may be considered as not really spent, but put into buildings, machinery, fixtures, &c., and which are available for further use; that is, they are amounts spent in view of work yet to be done.

The third column gives the amounts which have been really spent in the work, and which are of no further use except as they constitute a part of the expenses necessary in constructing the Tunnel:—

	Expenses for One Year.	Expenses of Further Use.	Expenses of no Further Use.
Engineering, Superin'dence, &c.,	$24,840 58	$13,135 91	$11,704 67
Deerfield Dam, ...	2,063 06	2,063 06	–
Excav. & Mas. East End Dam, .	266 60	266 60	–
Wheel-pits and House, . .	24,845 14	16,987 00	7,858 14
Gates and Overflow, . . .	566 53	566 53	–
Race or Canal, ...	2,064 51	2,064 51	–
East End Enlargement, . .	–	–	–
East End Heading, Hand Labor,	39,237 09	–	39,237 09
" " " Mach. "	32,068 48	–	32,068 48
" " " Enlargem'nt,	4,956 78	963 47	3,993 31
Central Shaft, ...	58,898 17	639 48	58,258 69
West "	103,263 09	–	103,263 09
West Approach, . . .	113,106 13	768 77	112,337 36
Building East End, . . .	3,837 34	935 22	2,902 12
" Central Shaft, . .	2,406 40	1,359 02	1,047 38
" West Shaft & W. End,	6,933 71	3,520 43	3,413 28
" General, . . .	1,842 98	1,842 98	–
Machinery Deerfield Dam, .	523 01	–	523 01
" East End, . .	66,494 59	64,278 69	2,215 90
" Central Shaft, . .	28,891 08	26,467 71	2,423 37
" West Shaft, . .	20,723 11	16,775 71	3,947 40
" West End, . .	503 27	–	503 27
" General, . . .	43,673 08	18,035 13	25,637 95
Land and Right of Way, . .	8,899 37	8,899 37	–
	$590,904 10	$179,569 59	$411,334 51

Taking the whole time since the assumption of the work, and the total expenses will be seen to be . . $1,482,973 20
Total amount put into buildings, machinery, &c., 673,531 24
absolutely spent in the work, . 809,441 96

The buildings and machinery represented by the above large outlay seem to have been necessary in the way of preparation for the energetic prosecution of the work. The enlargement must soon be actively entered upon, and if this is done by contract it will not perhaps be required of the State to erect many more buildings.

It will now be necessary without delay te add very largely to the present ability to pump water at the West Shaft, and soon to make provision for increased ventilation there. This will involve considerable further outlay for plant, but beyond this it is hoped that for one or two years very little more will be required, and that whatever is spent upon the work will be visible in actual progress, proportional to the amount provided.

Diagram No. 4 is a profile of the Hoosac Mountain, and upon it is indicated the amount of work already done.

THOMAS DOANE, *Chief Engineer.*

CONSULTING ENGINEER'S REPORT.

BOSTON, December 18, 1866.

To His Excellency Gov. BULLOCK, *and the Honorable Executive Council of the Commonwealth of Massachusetts.*

As Consulting Engineer, appointed under the third section of the Act approved May 30th, 1866, I beg leave respectfully to report, as contemplated therein and as requested by you, upon the progress and condition of the work upon the Troy and Greenfield Railroad and Hoosac Tunnel, and upon the plans for the prosecution of the same.

TROY AND GREENFIELD RAILROAD.

In my report on the 31st of August last, I communicated the result of my examination of the thirty miles of road between Greenfield and the Tunnel, and recommended that it be placed at once under contract, which has accordingly been done by the Commissioners with your approval.

The work is now reported by them to be actively progressing upon the thirteen miles between Greenfield and Shelburne Falls, the contractor confining his operations at present to this section of the route, as important to be opened first, and as containing the heaviest work. He is bound to complete it to Shelburne Falls by November 15th, 1867, and to the Tunnel by July 15th, 1868, and I think, may, with proper effort, anticipate both of these periods. As the road is extended, section by section, it will of course carry with it increased facilities to the work in the Tunnel by improved conveyance for hands and supplies, as well as bring the Tunnel from its present insulated position more into view, increase the interest felt in it by those

most concerned in its completion, and promote a more general appreciation of its magnitude and value. The lease of the thirty miles of the Fitchburg and Vermont and Massachusetts Railroad Companies, also recommended in my report just referred to, has been made, and the immediate extension of trade and travel over it, and of revenue therefrom, has been thus secured without farther expense to the Commonwealth.

Hoosac Tunnel.

Passing now to the subject of the Tunnel, I have respectfully to submit the following statements and opinions in regard to its condition and progress, and the best means of securing its speedy and economical prosecution. Having on the 12th inst. visited the work for the third time, and spent several days upon it in conference with the Commissioners and Engineer, I am enabled to express more decided views upon the points referred to in my previous reports, and of which I will now speak under their respective heads.

The Machine-Drills.

In my report of 29th October, I expressed a hope that the new machine then in preparation at Fitchburg, would be found to wear so much better than the one then in use, as to make its more rapid action when at work, substantially available to insure greater speed in the general advance of the heading. My expectations were not wholly disappointed, as the new drill, from its greater simplicity of form, and the smaller number of its parts subject to the most violent of the shocks experienced in its various movements, was found to require less frequent repairs. From carefully questioning the intelligent head mechanic, (Mr. Hall,) having charge of the machine shop at the east end of the Tunnel, I inferred that the improved machine was capable of doing full twice the duty of the previous one, and that its repairs would be less costly in even a more favorable proportion. In reply to my farther inquiry whether he considered the new machine susceptible of still further improvement, I understood him to say that he thought it could not be made *materially* better; that it was composed of as many distinct parts, (such as screws, pins, rachets, cams, pistons, &c., &c., amounting to no less than eighty in all,) as

the older machine; and although, as fewer of those parts accompanied the drill-bar in its blow against the rock, there would be less general wear and tear, the complexity of structure necessary to accomplish all the motions required of it must make it unavoidably subject to rapid wear and repeated breakage. There were six of the machines at the Tunnel during my visit, one-half of which were at work in the eastern heading and the other half in the shop, and of the three at work, one had its "feed movement" out of order, and was being fed by hand. Indeed I will here remark that, inasmuch as three men were required to operate each machine, the rotary and the forward or feed movement, or at least the latter, might perhaps better be done by one or more of them, and the parts of the machine now effecting these motions automatically, be dispensed with, to the simplification of the machine and its consequent improved wear. The danger, however, in this case would be, that a careless performance of the duty might lead to the binding of the bit in the hole, and to consequent breakage or loss of time in the operation of the machine, all of whose movements must be in that harmony with each other which can only be perfectly secured by making it automatic throughout. I must admit, that, on the whole, I was less encouraged by my late visit than before, to hope for improved progress in the work by the use of the machine, even in its improved form, and I am induced to doubt more than before whether an apparatus, necessarily so delicate in its structure and subjected to such incessant and violent shocks, can be made to do its work with *economy* and *rapidity* combined. The increased advance at Mt. Cenis, due it would seem to the machine drill, has been the foundation of expectation and effort in this direction for the three years which have elapsed since the Hoosac Tunnel became a State enterprise, and it would seem unwise, in the face of the success attending the use of such an instrument at that great work, to abandon the attempt to make it do here what it has done there.

Unfortunately, indeed, we are without specific or reliable information as to the Italian work, nor would it seem possible to obtain it unless by personal visit or minute observation; the professional journals and general press giving only vague and popular accounts of it. The drilling machine employed there,

as described by Mr. Storrow in his report to the Commissioners in 1862, and as shown by a drawing now in the office at North Adams was more bulky, cumbrous and complicated than the one first in use at the Hoosac Tunnel, the latter as stated by the Commissioners in their reports to the governor and council of January 1865 and 1866, being the result of their assiduous endeavors to avoid the defects of the Mt. Cenis machine. Yet the progress of the heading at Mt. Cenis was, as reported by Mr. Storrow, considerably expedited by the machine used there notwithstanding those defects, and it was reasonable to look for still better results at the Hoosac Tunnel, from a machine promising improvement in several respects.

The issue has, in fact, however, been otherwise, thus far, as the heading here, during the six months for which the machine-drill has been at work, is reported to be some 75 feet short of the point it would have reached at the previous rate of progress, by hand labor.

This unfavorable result, as regards forward movement, was compensated, in a measure, by the removal of more rock per linear foot of the heading, counted in cubic yards, and was also, no doubt, in good part owing to the very limited stock of machines in use, more than half of which have been in the repair shop at a time. Had a constant supply of machines been maintained, so that the moment one had become disabled another would have been substituted, the result would, doubtless, have been better.

Yet even in this case, it is evident that there must have been a much greater loss of time in detaching the drill from its carriage and attaching its substitute, than in changing a dull drill for a sharpened one in the hands of a miner.

In view of these circumstances and considerations, it appears that the alternatives now presenting themselves are,—

1. To proceed with the use of the machines now on hand, in their present improved form, and by multiplying their number as rapidly as possible, to avoid, as much as may be, the loss of time attendant upon their frequent breakage.

2. To discontinue their use for the present, and return to hand labor in the Tunnel until further experiments can be made outside of the Tunnel with this as with other forms of machine. Or,

3. To lay them aside entirely, and depend altogether upon hand labor for the future. I do not feel prepared at present to recommend the third of these alternatives, for I do not yet despair of ultimate success with some form of drilling machine; but I apprehend that until the drawbacks attendant upon the present machine—ingenious as it is, and superior as it is to its predecessor—are removed, a persistence in the present mode of operation will be attended with serious delays and a great increase of expenditure.

The progress at the east heading, from November 1, 1865, to June 8, 1866, (7¼ months,) was by hand labor 400.5 feet, or at the rate of 55¼ feet per month, while for the remaining 4½ months, (deducting a week of suspended work, while the machines were being introduced,) the progress was 191.5 feet, or at the rate of 42½ feet per month. I have not the data at hand to compare the relative cost of the two modes, but as the same amount of manual labor, powder, etc., was required in both cases, the expense of the machine-drilling must, notwithstanding the greater *proportional* number of cubic yards removed, have been the largest, not only on account of the slower forward progress, but the cost of repairing the machines. In watching the working of the machines, I noticed that the provision for injecting water into the drill-holes was but partially availed of, on account of its ejection in the faces of the miners when the holes pointed upwards, as they must do in the upper half of the heading.

This is a disadvantage in the use of the machine-drill which does not affect the hand-drill, the more rapid blow of the former tending to heat the bit, and by injuring its temper, cause it to wear much faster, and hence requiring water to keep it cool. It must also be observed, that with all the facility for directing the drill to different points, which the very well designed and constructed carriage affords, it cannot afford the miner the same means of using his skill and judgment in planting the drill holes so as to produce the best effects in blasting, and especially in the rock of this Tunnel, with its peculiar dip requiring the holes to be as much inclined upwards or downwards as possible. If it be furthermore contended that the machine-drill requires the heading to be driven at or near the bottom of the Tunnel, as it is being driven here and at Mt.

Cenis, it involves, in my opinion, an additional disadvantage in the economy of the work, of which I will speak more fully hereafter.

Reviewing the whole subject of the machine drill, as connected with this work, I would recommend the adoption of the second alternative above presented, viz., that the use of the machines in the Tunnel be discontinued for the present, and hand labor be resumed while the present improved machines, and any other which may be proposed and promise better results as to wear and tear, be subjected to thorough and continued trial at some suitable point in the neighborhood of the Tunnel, say at the eastern end, where the motive power is to spare, and the machine shop is under the direction of a skilful mechanic, familiar with such machines.

In suggesting this course, I think I am offering to this beautiful invention, so creditable to the mechanical genius of those who planned it, a better opportunity of establishing itself in the confidence of those in charge of this work and of the public at large, than if it should continue to operate under its present disadvantages within the Tunnel.

The interest which the Commonwealth has in the success of any machine which promises to promote the progress of this work, and to reduce its cost, or at least to hasten the time when its commercial advantages may be realized, should reconcile her to the moderate expense attendant upon the experiments proposed, insignificant as it must be, compared with that resulting from the retardation and increased cost of the work due to the conduct of the same experiments within the Tunnel. By the time these experiments will have reached some conclusive result, say within the next six months, more certain information may be obtained from Mt. Cenis, and the question be satisfactorily settled as to the real value of the machine drill. The progress made by hand labor in the east heading during the last year, has fully confirmed the estimate in this particular of the commissioners in their first report of February 28, 1863, having been 55 feet per month, as assumed by them, and also by Mr. Laurie in his report to them of January 10, 1863. Mr. Storrow put the probable progress at 60 feet per month in his report of November 28, 1862.

In my own report of October 1, 1862, I assumed 50 feet as the monthly rate, and am of course well pleased to find that I was quite safe in so doing. There has therefore been no disappointment in the actual result of hand labor on the end workings of the Tunnel, to which alone it was proposed to apply the machine-drills. It is indeed to be regretted that the naturally sanguine expectations of immediate success with the machines should have occasioned any delay whatever in the progress of the Tunnel; but the time lost on this account has not been great, and need be a subject of reproach to no one. I would add, that if the Commissioners think it best to postpone the withdrawal of the machines from the Tunnel, until farther experience be had of their work, with an increased number of them in operation, I see no objections to this course, as the machines can be used in the enlargement, of which I will speak hereafter.

PRESENT CONDITION OF THE WORK AND PROGRESS TO THIS TIME.

The railroad between Greenfield and North Adams was taken possession of by the Commissioners in September, 1862; and the condition in which they found the work, in all its parts, as left by the former contractors, Messrs. Haupt & Co., is exhibited in their two first reports to the governor and council, of February 28, 1863, and January 12, 1865. When the work was resumed by the State in October, 1863, there had been driven by the contractors 2,124 feet of tunnel at the East End, about 14 feet wide, by 18 to 19 feet high, intended by them as the full section of the Tunnel, when completed and designed only for a single track.

In advance of this, there was 270 feet of heading, the whole amount of excavation being about 17,000 cubic yards. The West Shaft was sunk to grade, and headings, 32 feet east and 25 feet westward, had been driven by the contractors as a commencement of the Tunnel proper at that point. At the West End, the approach cutting had been made, and some 550 feet of tunnel driven, and in part supported by timbering, and in part arched with stone. A good portion of this had broken in from above, and the Commissioners having decided, in concurrence with the advice of Mr. Laurie and myself, to raise the grade at this point from 25 to 30 feet, it was deter-

mined to extend the open approach cut so as to supersede this piece of tunnelling. It was accordingly so arranged; and the total length of the Tunnel would have been thus reduced 988 feet, or from 25,586 feet, as ascertained by careful re-survey, to 24,598 feet, or $4\frac{660}{1000}$ miles. The Commissioners, however, subsequently decided to raise the grade at the West Portal only six feet above its level, as established by the tunnel of Messrs. Haupt & Co., and to shorten the Tunnel only 624 feet, or to 24,862 feet, or $4\frac{709}{1000}$ miles. The reasons for this change of plan are not stated in their report of December 20, 1864; and the report of the Chief Engineer, Mr. Doane, simply states the fact of the change, and refers to its approval by the Commissioners. I have seen no reason to change the views expressed in my report of October, 1862, in favor of an elevation of the level to the full extent of 25 feet at this point, and cannot but regret that it was not done; but the large amount of work already executed in the present location, at a heavy expense, forbids the idea of abandonment now.

The lower grade has the cheapening and shortening to some extent of the line between North Adams and the Tunnel, to compensate in a measure for the increase in the length of the Tunnel, as above named, and of the difficulties which may be attendant upon driving it through the decomposed rock west of the West Shaft.

The able and elaborate report of the Commissioners of February 28, 1863, fully details the plan on which they proposed to conduct the work.

The adoption of a Central Shaft was a judicious measure, and, as I will show farther on, will greatly expedite the completion of the work.

Had the work at the West Shaft progressed as fast as was then presumed, the Central Shaft might have been sunk where the ground was some 300 feet lower, at a considerably less expense, and with nearly equal effect in advancing the work in the Tunnel. As the whole work now stands, it is, however, in about the best position for the last-named object.

One of the first measures of the Commissioners was an accurate retrace of the line of the Tunnel, by which re-survey it was discovered to deviate from a perfectly straight line, and the mode adopted by the Chief Engineer, Mr. Doane, of correct

ing this with the least sacrifice of work done, was judicious, and is described in his first report.

It is certainly better to have the Tunnel perfectly straight, although not indispensable, provided the curvatures were very gentle. It is not to be apprehended that there will be any failure in the meeting of the different workings, but should they not hit exactly it is well to know that a partial miss will not be fatal to the work.

WORK DONE UNDER THE COMMISSIONERS SINCE THEY TOOK CHARGE.

First.—At the East End. The State having taken up this part of the work where the contractors left it, the bottom or floor of the Tunnel, where it had the full section of fourteen by nineteen, was first brought to a regular grade. This was a tedious and expensive operation, and occupied an entire year, and until it was completed no advance was made in the heading or enlargement.

I will have occasion to offer a remark in this connection farther on.

The bottom of the contractors' tunnel having been then regularly graded on an ascent of about eighteen feet per mile up to the breast where the contractors' heading began, 2,124 from the East Portal, the next operation was to reduce the bottom of that heading, which extended about 275 feet beyond the breast to a height of four and one-half feet above grade, instead of the twelve feet at which it had been driven by Haupt & Co.

It was also widened to fifteen feet, from eleven feet, its previous width.

This additional move then brought the Commissioners' work up to the extreme end of the contractors' preceding work, at a distance of 2,399 feet from the East Portal, and this event took place, as stated in the Chief Engineer's report of December 15, 1865, on the fifteenth of March of that year, since which date the work has consisted of the new heading carried on by the State. On the first of November, 1865, it had reached, in seven and one-half months intervening, a distance of 2,839 feet from the East Portal, the total progress being 440 feet, at an average rate of sixty feet per month very nearly. In the month

of August, 1865, sixty-nine and one-half feet were driven, and in October, sixty-three and one-half.

The advance was therefore very encouraging, and was effected entirely by hand labor, showing what that sort of labor could accomplish. The widening of the heading from eleven to fifteen feet worked extremely well, as shown by Mr. Doane in his report now quoted, where it is seen (page 43,) that the enlarged section improved the useful effect of the manual labor in a remarkable degree, viz.: in the inches of holes drilled, 40 per cent.; in cubic yards of rock removed, 70 per cent.; and in forward movement of the work, 23 per cent. From this valuable experiment we must observe how much more economically the whole work of tunnelling can be done with a large than with a small area. From November 1, 1865 to November 1, 1866, the east heading progressed 592 feet, and reached a point 3,431 feet from the East Portal, the advance being at the rate of a fraction less than fifty feet per month.

As already stated, however, when treating of the machine-drills, the slower progress made by them during the last four and one-half months of the year has affected the general result; the advance by hand labor in the seven and one-fourth months from November 1, 1865 to June 8, 1866, being fifty-two and one-half feet per month, while that of the machines in the four and a half months from June 14 to November 1, 1866, was forty-two and one-half feet per month, which is about the rate at which the heading is advancing since the first ultimo. I will have occasion hereafter to recur to this statement of progress at the East End.

Central Shaft.—The work here was begun in December, 1863, and at the date of the Chief Engineer's report of September 19, 1864, it had been sunk about seventy-four feet, of which twenty-five was through earth, and the rest through rock. Much time was necessarily consumed in the preliminaries of this work, such as the walling of the upper section to secure it from caving, and provide a foundation for the house to contain the hoisting, pumping and ventilating machinery, and the apparatus for lighting. It is not to be wondered, therefore, that in a locality difficult of access like this, their preparations should have consumed so many months, and this could be better

understand if the substantial structure of the buildings and the superior quality of all the machinery were personally seen. The purchase of the farm on which these improvements stand was a very judicious measure. The sinking of the shaft was suspended from September 23, 1864 to March 22, 1865, while waiting for the improved machines, and by November 1, of the last year it had reached a depth of 201 feet. Its average rate for the seven and one-fourth months was nearly eighteen feet per month, and in August of that year 23 feet was made. This was, on the whole, encouraging, as the Commissioners had allowed a progress of twenty feet per month, Mr. Laurie twenty-one, Mr. Storrow twenty-one and five-tenths, and myself but sixteen and two-thirds feet in our reports of 1862.

From November 1, 1865 to November 1, 1866, the total progress was, however, but 154 feet, which would have been at a little less than an average of thirteen feet per month; but from May 6th to August 1st of this year, the work was entirely stopped to introduce further new machinery, so that it was in motion for only nine and one-fourth months, and made sixteen and two-thirds feet per month. Neither of these two years' operations afford a fair test of further progress, as the introduction of new machinery not only stopped work for the time, but checked it both before and after. The depth sunk in October last was twenty-three feet at upwards of 350 feet down, and I see no reason why a speed of at lest twenty feet may not be accomplished, unless water, of which there is now very little in the shaft, should break in abundantly. The firing of the blasts by electricity at the same instant has greatly helped their effect, and promoted the safety of the hands as remarked by the Chief Engineer in his reports. The character of the rock is more favorable here than it has so far proved in the body of the Tunnel, both as to ease of drilling and blasting, and freedom from wet.

West Shaft.—This shaft, as above stated, having been found completed, and headings in both directions begun from it by Haupt & Co., work was commenced in it under the Commissioners in March, 1864, with the contractors' machinery, with which ninety-six feet east and one hundred and thirty feet west headings were driven, when the work was stopped, November

12, to put in the new machinery ordered in the spring of that year.

The shaft was pumped out so as to permit the work to proceed again on the first of January, 1865, and by the fifteenth of February following had advanced twenty-six feet east and thirty-five feet west, when the disturbance among the workmen, described by the Chief Engineer in his report of December 15, 1865, which resulted in the burning of the shaft-house and blacksmiths' shop, compelled a suspension of the work until the buildings and machinery were restored and progress resumed on the fifteenth of May in that year. The total advance previous to that date had been only 122 feet east and 165 feet west from the shaft, or, adding what the contractors had before done, 154 feet east and 190 feet west. The imperfect old machinery and the suspensions occasioned by that cause and the destruction of the new machinery and buildings explain this very slow progress for the first year of the new administration. The work being fairly recommenced on May 15, 1865, has made steady progress since, and on November first of the same year had reached a distance of 367 feet east of the shaft. The headings west of the shaft had been stopped on the second of August of last year, in order to await the sinking of a supplementary shaft, to be spoken of presently, and had, at that date, reached a point 281 feet from the shaft. On the first of November of the present year (1866,) the east heading had arrived at a point 990 feet from the shaft, the west heading remaining stationary, as just mentioned. The progress in the *east* heading was, therefore, during the five and a half months preceding the first of November, 1865, thirty-nine feet per month, while, for the twelve months to November first of the present year, it has been fifty-two feet per month on the average, and during the six months immediately preceding that date the average progress has been sixty-two feet per month, sixty-four feet having been driven in July last. This recent advance in the working from a *shaft* is more rapid than was estimated by any of the engineers who reported in 1862 and who allowed a progress of from thirty-three and one-third feet to forty feet in the shaft headings, excepting Mr. Storrow, who made no difference in the rate from that of an open end heading, putting both at an average of sixty feet per month, and so

far the latest results would show him to have been the nearest right. A fair test, however, of relative speed of advance in the two sorts of working has not yet been had, and, when both are progressing under the circumstances most favorable to each, the headings from the open end will be found to go the fastest. The results in the West Shaft are, however, very encouraging in this as well as every view. The headings in this shaft, both ways, were driven at the bottom of the Tunnel, allowing, however, for drainage, a slight slope towards the shaft in the west heading having been so begun by Haupt & Co. and continued by the Commissioners until, in August, 1865, the *east* heading was raised from the sub-grade (or bottom,) to four and a half feet above that level at which it has since been carried on. These headings, both ways from the West Shaft, at first had a section of six by eleven feet, then enlarged to six by fifteen for their whole lengths, and since farther enlarged to ten and a half by fifteen for a distance of 750 feet eastward and 230 feet westward from the centre of the shaft, from which central point all the above measures are counted. It was in the east heading of this shaft that experiments with nitro-glycerin as an explosive were made, under the direction of Col. T. P. Schaffner, in September last, and with highly favorable results, as reported by the Chief Engineer, who states the forward progress in the heading proper (six by fifteen in section,) as *doubled*, and in the heading enlargement (to ten and a half and fifteen,) as *trebled*, by this new agent when compared with gunpowder. He also reports $10.20 per cubic yard saved in the heading, and $3.64 in the enlargement, on a similar comparison with gunpowder, results certainly of the most encouraging character, and inviting to farther and persevering effort for the safe and successful use of the new explosive.

The hoisting machinery at this shaft has operated as well as would be wished since its erection, and the pumps have also performed well up to the limit of their capacity which, when increased by the enlargement of the "plunger," was equal to the raising of about 140 gallons per minute. The quantity of water in the headings has, however, been gradually increasing until within the last month it became so much beyond the ability of the pump as to render necessary a suspension of the work, which must continue until a new pump of much larger

power is introduced or auxiliary means are employed to keep down the additional influx. The latter alternative will be resorted to, as I understand, for the present at least, so as to permit the work to be shortly resumed.

Supplementary Shaft.—The west heading of the West Shaft having been stopped on the second day of August, 1865, for the reasons given by the Chief Engineer in his report of December 15 of that year, the new shaft now referred to was begun on the eleventh of December, 1865, at a distance of about 264 feet west of that shaft. Its depth, when completed, will be 277 feet, and its section 6 by 13 feet, to be divided into two compartments of 6 by 6, with a pump in each. The bottom of this shaft falls *within* the west heading of the West Shaft, so that it will supersede the latter altogether, at least for raising water from the tunnel. The advantages to be derived from it are: 1st, a longer base from which to extend the line of the tunnel eastward, and a test of this line already followed. 2d, a reduction of lift for the water, equal to the difference of 39 feet in the depth of the two shafts, (the West Shaft being 316 feet deep,) increased by a small horizontal driftway, which has been made to perforate the ground 41 feet below the top of the Supplementary Shaft, thus making the whole reduction of lift 80 feet. This driftway is about 100 feet in length, with fall enough at its outer end to carry of the water freely, when raised through the shaft. The Chief Engineer in his present report, which he kindly allowed me to see, has fully explained his motive for sinking the Supplementary Shaft no farther west, where it would have had much less depth. In my report of the twenty-ninth day of October last, I assumed, from its previous progress, that seven or eight months from that date, would probably be required to complete it. At my recent visit to the Tunnel, I was, however, gratified to find that it had progressed so much faster than before, that there remained but sixty-three feet to complete it, and that as it was also being worked upwards from the bottom, it would be finished, probably, in February next. If the auxiliary means for freeing the West Shaft headings from water, above referred to, should not prove sufficient to permit the resumption of work therein, the early completion of this new shaft, to which the machinery should at once be removed, should, in view of the

reduced height to which the water will then have to be raised, allow of the recommencement of the east heading soon thereafter. The Supplementary Shaft has been sunk by contract.

Trial pits and borings, between West Shaft and West End.—Between the Supplementary Shaft and the West End, four of these pits or wells were sunk on the line of the tunnel, and three of them were continued down, or near to the grade of the road, by borings. The minute description of them by Mr. Doane, in his report of December 15, 1865, with his additional reference to them in his present report, renders unnecessary a more particular account of them here. They all developed facts of interest in regard to the character of the ground to be met with, in executing the part of the Tunnel between the west heading of the West Shaft, and the West End, showing that wet work must be expected; but that rock, although in a soft and saturated condition, will be found throughout the whole distance of two thousand feet. This material, although requiring more than ordinary precaution in drainage, excavation and arching, is more favorable than the dry quicksand and boulders encountered by Haupt & Co., in the work done by them at the West End of the Tunnel, as then established, but since altered by the Commissioners.

West End.—The Chief Engineer in his reports of September 18, 1864, and December 15, 1865, gives a detailed account of the circumstances under which this interesting section of the work was commenced and carried forward to that date. The Commissioners, as appears from their report of February 28, 1863, had decided to move the West Portal nine hundred and eighty-eight feet east of the point at which it had been fixed by Haupt & Co., and so shorten the Tunnel to that extent. This purpose, however, was coupled with the design of raising the grade some twenty-five feet above that on which those contractors had built their work. When, subsequently, it was determined to lift the grade only six feet, the Portal was placed as would appear from the profile furnished me by Mr. Doane, about three hundred and sixty-four feet *west* of the point selected by the Commissioners, and six hundred and twenty-four feet *east* of the portal of the contractors' tunnel. The fourteen months

elapsing from the passage of the work into the hands of the Commonwealth, up to December, 1864, were occupied in excavating as an open cut, the difficult and treacherous ground lying immediately east of the abandoned work of Haupt & Co. A heading was then begun in the soft rock which had been reached, and carried forward about one hundred and thirty-nine feet, but as it caved in at the forward end, up to the surface of the ground, it was suspended, and time taken to consider the best means of proceeding farther with the work, involving, as it did, the progress of the Tunnel through the long distance of doubtful material all the way to the west heading of the West Shaft. The working season of 1865, and the spring of 1866, passed in sloping and securing, by retaining walls, the open cutting; and a contract was then made with Mr. B. N. Farren, for arching one hundred and seventy-four feet of the Tunnel, from the West Portal, eastward to where the open cut, in which this section of the work was to be built, and afterwards filled over, came to an end, and drifting under ground, would again begin. The contract farther provided, that at least two hundred feet more arching should be done east of this point, and of course, as a subterranean work, on or before June 30, 1867.

Work was commenced under this contract on June 7, 1866, and by the end of November, ultimo, the open cut part of the arch was brought up to the breast, and the brickwork, at my recent visit, had fairly entered the drift in which it is hereafter to advance eastward. Some months ago, a heading had been carried about 40 feet into the hill from this breast. Its position was at the top of the section of the Tunnel, and as the ground proved wet and difficult as it advanced, another and smaller drift was driven underneath at the bottom of the section, and pushed some 80 feet inwards, with a view to drainage. From the end of this last drift, two lateral and smaller drifts have been carried forward, curving outwards at first, so as to clear the Tunnel area, and afterwards proceeding in lines parallel to the line of the Tunnel, and about 15 feet therefrom. The southerly one of these drifts has penetrated about 220 feet eastward from the breast above mentioned, and the northerly one more than half that distance. They disclose wet ground, consisting of soft rock, mostly saturated with water. Their purpose has been to cut off the springs on either side from the

Tunnel area, so as to dry the latter as far as possible, and facilitate the drifting and arching. The aggregate discharge of water from these draining drifts, as roughly gauged in October last, was about 70 gallons per minute; but is probably more at this time, and may increase to much more still during the coming winter and spring, from snow and rain.

The contractor is pushing his work forward, supporting the roof and sides of the excavation, by timbering in the manner usually adopted in such tunnelling, and having experienced miners to direct the work in detail, is making pretty fair progress. From present appearances it would seem that a "shield" on the plan alluded to in my report of October 29th, may be dispensed with; and if so, the work can proceed more rapidly and cheaply on the method now in operation, or some improvement on it hereafter to be devised.

Road between the Tunnel and the Village of North Adams. This part of the road has been surveyed on two lines diverging near the West End of the approach, cut and reuniting about half way from thence to the site of the station grounds in the village. They differ very little in length, (only 34 feet;) the most southerly is the most direct, while the other, although with more curvature, requires about 94,000 cubic yards less of embankment upon it, and will do much less injury to the farms intersected. The excavation in the approach cut, and in the Tunnel, applicable to the embankment westward, will more than make it on the northern line, but will fall considerably short of so doing on the southern line. The northern line will thus be found considerably the cheaper; and, although not quite so straight and handsome a line, will, I doubt not, obtain the preference when a final location comes to be required. Such a location should not be much longer postponed, as land is rising in value, and especially within the village of North Adams; the line should be fixed, station grounds selected, and right of way secured, as improvements are growing up daily which will greatly increase the expense of this item. In the report I had the honor to make on the 31st of August last, I called attention to this subject, and, having concurred with the Chief Engineer as to the proper line through the village and the best site for the station, I had regarded these questions as settled,

and, in this impression, I believe the Commissioners are also agreed.

I have availed of the present occasion to give the preceding history of operations at the Tunnel since the Commissioners took charge of them three years since, believing that a connected narrative, gathered from the periodical reports, would not be unacceptable at this time, and especially as it will enable me more conveniently to refer to the past experience of the work in expressing my views as to its future conduct. Before proceeding however to submit the opinions I have been led to form in this regard, I will speak briefly of the

COST OF THE WORK TO THE PRESENT DATE.

First, Cost of the Road between Greenfield and the Tunnel.—The documents in my possession do not give me the means of stating the cost of the 30 miles of road east of the Tunnel, or of the Tunnel itself, prior to their passage into the hands of the Commissioners, from those of the contractors, Messrs. Haupt & Company, in October, 1863. No work having been done (until very recently under the new contract,) under the Commissioners on the road east of the Tunnel, I can only refer to the *estimate* in their first report of February 28, 1863, wherein (page 32,) they put the expenditure required to open the road from Greenfield to the Tunnel at $497,061 — to which they add $75,000 for rolling stock required to work it — making a total of $572,061. As the contract executed in October last with Mr. Farren provides for the completion of this division of the road at a sum within this estimate, and the lease of the road to the Fitchburg Railroad Company and the Vermont and Massachusetts Railroad Company, obviates the necessity of any outlay on the part of the Commonwealth for rolling stock, this item of expenditure under the Commission may be considered as liquidated.

Cost of the Tunnel.—Confining, as explained above, my statements under this head to the expenditures by the Commissioners, I have before me an abstract of those expenditures, from their commencement in October, 1863, up to November 1, 1866, which I have classified as follows in accordance with the division of them in his annual report to the Commissioners,

by Thomas Doane, Esq., Chief Engineer, through whose kindness I have been furnished by them. The items treated by him as "buildings, machinery, fixtures, &c., not really spent, but available for further use," I call "outside;" and those "really spent in the work and of no further use except as they constitute a part of the expense necessary in constructing the Tunnel"—I call "*inside*" expenses. It will be seen that the former class bears a very large proportion to the latter *thus far*, amounting, indeed, to nearly one-half of the whole expenditure — a fact which may naturally surprise and even startle at the first glance, and before the great magnitude of the work and the small part of it *yet done* is properly considered.

EXPENDITURES UNDER COMMISSIONERS ON HOOSAC TUNNEL.

I.—*Outside Expenditure.*			
Deerfield Dam, ...		$244,912 29	
Buildings, East End, . .	$31,688 99		
Buildings, West End and West Shaft, ...	40,010 13		
Central Shaft, ...	12,026 83		
General amount, . . .	9,537 37		
		93,263 32	
Machinery, East End, . .	$87,032 38		
Machinery, West End, . .	539 89		
West Shaft, ...	57,111 73		
Central Shaft, ...	51,364 01		
Deerfield Dam, . . .	10,820 93		
General accounts, . . .	62,600 76		
		269,469 70	
Land Damages and Land, ...		17,513 21	
Engineering and Superintendence, . . .		84,840 48	
Total Outside Expenditure, . . .			$709,999 00
II.—*Inside Expenditure.*			
East End Heading, . . .	$103,731 45		
E. End H'd'g Enlargement, .	17,559 46		
E. End Bottom Enlargement, .	80,317 10		
		$291,608 01	
Central Shaft, ...		144,423 75	
West Shaft, Headings, &c., ...		179,041 69	
West End, Approach Cut, Drifting and Arching,		247,900 75	
Total Inside Expenditure, . . .			772,974 20
Total Expenditure to November 1st, 1866, . . .			$1,482,973 20

To be enabled to judge whether the expenditure above stated bears a proper relation to the amount of work not only already done, but to be done hereafter, we must, of course, know what that amount in fact is, and will be, when the work is completed; nor is it less necessary to consider all the circumstances which have affected the past and may affect the future cost of the work. I am not as yet provided with the particulars of the work either done or to be done, expressed in the usual measures of quantity, and although I have made approximate estimates thereof, I hesitate to apply them to the work *already done*. I deem it, then, prudent to say only thus much as to the cost *per cubic yard* of the work done in the Tunnel and Central Shaft *thus far*. 1st. That it would manifestly not be fair to charge it with the whole expense of the *outside* work, as that must be divided among the entire number of cubic yards in the Tunnel and shaft *when completed*. 2d. That it would neither be fair to estimate the cost of future work by what the work now done has cost per cubic yard up to this time on the basis of the *inside* expenditure alone. The many embarrassments and difficulties attendant upon the commencement of a work of such unprecedented extent, and in some respects novel character, and upon the control of so large a body of operatives in a remote and thinly settled region, the excessive cost of labor, and the often insufficient supply of the sort most wanted, the delays in procuring the machinery and material for making the manual labor most effective, the heavy expense of transportation between different parts of the work over such a mountain and such roads, these and other circumstances afford, in a good degree at least, an explanation of what has undoubtedly been an unusually large expenditure in comparison with the results obtained so far. To this we may add the almost invariable and inevitable excess of cost in work done by the day over that done by contract, especially on so large a scale as the present. With these general remarks as to the cost of the work already done, and begging leave to refer to the Commissioners for more detailed statements under this head, I would proceed to speak of the probable cost of *completing* the work from this time out, in connection with such suggestions as I have respectfully to offer as to the mode of conducting it in the future.

FUTURE PROGRESS OF THE WORK AND RECOMMENDATIONS WITH A VIEW TO INCREASED SPEED AND ECONOMY.

I would commence what I have to say under this head, by remarking that whatever opinions may be entertained as to a part of the system of machinery employed to carry on the work, (the Deerfield dam for instance,) it must be admitted that the structures and machines themselves are of the best construction of their respective kinds, and that they have performed their duty efficiently. It is true that more pumping power is now urgently required at the West Shaft, and that more will also be probably needed at the Central Shaft as it sinks, and more hoisting power necessary when it reaches the grade of the Tunnel, and tunnelling from it begins. It would be well indeed if the excess of power furnished by the Deerfield dam could be made effective at the Central and West Shafts, but that not being practicable, these points must be otherwise provided for, as their wants require. This provision will not involve a very heavy outlay, and when made it will close the machinery account. I would now recommend the following changes in the plan and mode of carrying on the work hereafter.

1st. Slight Change of Grade in the Tunnel.

The grades within the Tunnel, as now arranged, are about as follows: From the East Portal to the Central Shaft, a distance of 12,821. feet, (2.428 miles,) the ascent is at the rate of 18½ feet per mile. A level then extends about 1,390 feet (.263 of a mile,) from the Central Shaft westward, and from its termination the descent for 8,336 feet (1.584 miles,) is at the rate of 21⅛ feet per mile to the West Shaft, whence for 2,284 feet (.432 of a mile,) to the West Portal, the descent is 26½ feet per mile—the two portals being precisely at the same height of 766 feet above tide-water. I would propose to modify this grade to the following extent, viz.: From the East Portal ascend at 21⅛ feet per mile to the Central Shaft. A level of 898 feet long from thence westward, and then a descent of 23¾ feet per mile, to the West Shaft and a junction with the present grade thereat, whence to the West Portal the existing grade of 26½ feet per mile would remain unaltered. I would have proposed a more decided change in the grades, but for the restraint imposed by the work already done, and which will be very

slightly affected by the alteration now suggested. The advantages to accrue from the change will be a more rapid drainage in each direction, resulting from the stronger slope both ways, and the shortening of the summit level. The steepening of the grade on the east side of the summit so as to insure the downward passage of the trains by gravitation, and without the use of steam and consequent evolution of smoke—the cutting off about 6½ feet from the depth of the Central Shaft. The last item is not of much account, and is mentioned only as incidental to the others. I attach considerable importance, however, to the two first items, as a free escape of water from the Tunnel will tend to lessen the dampness so prejudicial to the adhesion of the locomotives—and as the large preponderance in freight will be in the eastward direction, and hence much the most tractive power required to draw the trains that way, it is desirable to give them all practicable assistance in their passage, for the descent of a train by gravity alone, along a grade of 18½ feet per mile, requires a reduction of friction in the cars within the usual limit, while a grade 21⅛ feet per mile, will usually give motion without other motive power. A grade of 26½ feet per mile, I should have preferred, but on examining carefully the effect of its adoption at the East End on the work done there, I concluded to compromise upon the lesser one. As from the West Portal to the shaft, the grade is already established beyond change at 26½ feet per mile, ascending eastward against the heavy trade, the gentler of 23⅝ in the same direction cannot be objected to.

2. *Enlargement of Tunnel, and Change of Position of Heading.*

I advise that the enlargement of the Tunnel be at once commenced, both at the East End and the West Shaft, in the eastward direction, and that the headings be suspended until the full section of the Tunnel is taken out quite up to them; that the position of the headings be then changed from their present level of four and a half feet above the grade to about fifteen feet above grade, with a height of seven feet at the crown of the arch, and fifteen feet width, the whole depth of the section being assumed at twenty-two feet, and width, at chord line of semi-circular roof, twenty-five feet, and at grade or bottom, twenty-three feet, with an area of fifty-six and six-tenths square

yards. In the progress of the work thereafter, should this change of plan be adopted, I would recommend that the bottoming be kept as close to the heading as may consist with convenience and safety. If hand labor be used in the heading, it can be worked within fifty feet of the bottom, or even less, (a proper slope being allowed between the two,) as the purpose of the heading as an advanced opening into the rock, would be as fully answered as if it were an indefinitely greater distance forward. If machine drills be employed, the heading must be kept considerably farther in advance, in order to allow the drill carriages to be run back out of the way of blasts. My reasons for the preceding recommendations are stated briefly thus:

The position of the heading at the top of the Tunnel section will avoid the use of scaffolding in the enlargement; will be attended with less injury to the tracks from the fall of the rock when thrown out by blasts; will cheapen the drilling by permitting the holes (in the bottom or enlargement,) to be made vertical, thus relieving both the holder and striker, and will make the force of the powder in this highly inclined stratification more effective; will save expense in *trimming*, which, with the heading at the bottom, must be done *twice*, first to the temporary and afterwards to the permanent roof; will allow the bottom enlargement to be kept up much closer to the heading, especially if the drilling is done by hand. It will thus save much handling of material. It will also help ventilation by keeping the section of the Tunnel its full size, and giving room in its upper portion, where no work is doing, for the smoke in most conditions of the atmosphere. It will permit a double track of the ordinary gauge and cars of the full size to come near the breast and receive their loads without so much obstruction from fragments of rock. If the roof should prove unsound at any point, the fact is at once discovered, and means adopted to support without interference with the subsequent enlargement or disturbance of the props introduced.

The arguments in favor of the heading at or near the bottom, do not, in my opinion, balance those on the other side. It is true that the weight of the rock in enlarging at the top assists the force of the explosive in blasting; but the claim of better drainage with the bottom heading is not well founded, as the

central drain can as well or better be opened and maintained in the enlarged section when the heading is at the top. The continuity of the tracks in the bottom heading would be of advantage only in case the small cars used in the heading were run all the way out to the Portal, which would be bad economy. It is better to bring up the large cars and shift the load of the small cars into them, which can better be done by dumping from a higher level than lifting from a lower one, the inconvenience of which is noticed in Mr. Storrow's report on the Mt. Cenis Tunnel. The objection to the top heading, that its material has to be thrown down over the fall of the enlargement breast, may be obviated by proper dumping arrangements, if the heading were so far ahead of the bottom as to make the use of small cars necessary. The two workings, however, if by hand, should be kept so close that, the blasts being all fired at once, most of the heading material will be thrown over the breast by the force of the explosion, and what remains can be thrown over by hand when the men are at meals. The reason in favor of the bottom heading, on which most stress has been laid, is the supposed facility it would afford for carrying on the enlargement at a number of points, supposing the heading to be completed altogether in advance of the enlargement. If the heading were in fact so driven through in advance, it would be at a greatly increased cost of ventilation, drainage and effective force of the blasts, as well as of transportation, which would have to be done altogether in small cars. But it is not considered as really practicable so to conduct the enlargement, as the small section of the heading, the crowded condition of the work therein, the narrow tracks, small cars, bad ventilation and drainage and obstruction to the tracks from fallen rock, interference with each by passing cars, &c., would produce inextricable confusion, and so reduce the transportation facilities as to make the plan incapable of execution. The saving of *interest*, by thus putting off the expense of enlargement, would not compensate for the other disadvantages of the plan. Indeed, as, with the heading at the top, the whole section of the Tunnel can be carried on *pari passu*, the very earliest possible opening of the whole work can be thus accomplished, and its commercial advantages, the main motives to its construction, soonest realized. The popular

favor to be won by proclaiming that "the mountain had been pierced through and through," would be a very ephemeral and unsubstantial set-off to the after-claps which would come in the almost insurmountable difficulties of the enlargement, without which enlargement the mere "hole in the hill" would be worth nothing, and but an empty boast. The true foundation for favorable reports of the progress of the work to the legislature and the public would be the number of cubic yards taken out, and the tunnel so far finished and ready for use at each step of its advance. I would therefore earnestly recommend that *this* plan be pursued in the further prosecution of the work.

8. *Central Shaft.*

I have only to say of this that its vigorous prosecution should be uninterrupted, with its present effective machinery, assisted by such additions as may be found necessary hereafter, when the Tunnel is reached, and increased means of ventilation, drainage and transportation are required.

West Shaft.—The enlargement at the West Shaft, above advised, in the eastward direction, should also be proceeded with in its westward working, so that when the Supplementary Shaft is completed, and the pumping and (if there be room for it,) the hoisting machinery removed to it from the West Shaft, the Tunnel may be driven westward from the new shaft to meet the eastern working from the West End, which should be advanced as far as practicable, in order to get rid of the expense of raising water and material from this shaft.

West End.—The only recommendation I have to make, in connection with this part of the work is, that it be steadily advanced at the best speed which its peculiar difficulties will admit of. I am not sure that the use of a cast-iron arch, applied in a manner suited to the case, would both hasten and cheapen the work here, and I propose to give particular attention to it on my next visit to the Tunnel. There will be time to mature any such improvement in plan before the contractor will have carried the brick arch to the limit provided for in his agreement.

EXTENSION OF THE CONTRACT SYSTEM TO THE REMAINDER OF THE WORK.

Under this head, I would prefer at present to suggest inquiry, rather than offer positive recommendation, (although I decidedly favor the policy,) and as the Commissioners have the subject under consideration, it will be as well to leave it in their hands. I cannot but believe that as the work is now, or shortly will be, situated, it may be so divided as to let out to individuals, or firms of contractors, at stipulated prices, with advantage in many ways. The number of the divisions would naturally be *four*, viz., the *East End*, the *Central Shaft*, the *West Shaft, and the workings both ways from it*, and the *West End*, with its approach cut and the mile of road between the Tunnel and North Adams nearest the Tunnel, as its embankment would be made from that cut and the Tunnel. The mile of road next to and through North Adams, needs only to have the right of way and station grounds on it secured for some time to come. The detached position of the several divisions of the work above mentioned would permit them to be carried on under separate contracts. They could not, however, be further sub-divided without danger of collisions. If general competition were invited, the work could be let at reasonable prices, and this remark leads me to speak of the

PROBABLE TIME OF COMPLETION, AND COST OF THE WORK.

Estimates both of time and cost, in a case like the present, must be offered with some degree of reserve; yet I do not feel much hesitation in submitting the following opinions as to the period at which the completion of this great work may be reasonably looked for; and as to the amount which should suffice to finish it:—

1st. Time necessary to complete the Tunnel.

An inspection of the profile of the Tunnel and approaches, shows that the mountain has been penetrated from the *East End* to a distance in round figures of 3,500 feet; from the *West Shaft*, eastward, 1,000 feet, and westward, 280 feet; and from the West End, about 180 feet of arched tunnel has been

constructed. The Central Shaft has been sunk, we may say, 390 feet at this date. As the whole length of the Tunnel, from its eastern to its western Portal, is 24,862 feet, and work has been done upon 4,960 feet, there remain 19,902 feet, linear, on which nothing has been done in the line of the Tunnel, and as the Central Shaft, when sunk to grade, will be 1,030 feet deep, (supposing the change of grade suggested above be made,) there remain 640 feet untouched in this shaft.

If the change in the manner of carrying on the work above suggested be adopted, and the headings be suspended until the enlargement be brought up to them, the time required for these enlargements must first be fixed. To do this, the number of cubic yards to be removed must be estimated, and in computing this (approximately) from the data I have at hand, I will assume, for the present purpose, (although it is a little larger than the size above mentioned,) the area of the completed Tunnel when executed in rock, without allowance for lining with brick or stone, to be 54 square yards, which I judge to be very nearly the section proposed by the Chief Engineer in his report of December 15, 1865, (page 29.) There will then be 18 cubic yards for every linear foot of the Tunnel.

East End.—3,500 feet linear, at 18 cubic yards per foot, ...		63,000 c. yds.
From this take Haupt & Co's. work, estimated at, say, .	17,000 c. yds.	
And Commonwealth's work, estimated at, say, . .	9,000 "	
		26,000 "
Which leaves to be taken out in enlargement,		37,000 c. yds.

If now we allow $\frac{3}{4}$ of a cubic yard to represent the day's work of each man employed in this part of the Tunnel, and 250 men to be the average force, there would be $187\frac{1}{2}$ cubic yards removed per day, and the whole 37,000 yards in 200 working days; or say eight months of 25 days, to complete the East End enlargement.

West Shaft, Eastward.—1,000 feet, linear, at 18 c. yds. pr. foot, ...		18,000 c. yds.
West Shaft, Westward.—280 feet, linear, at 18 c. yds. pr. foot, ...		5,040 "
Making 1,280 feet, linear, at 18 c. yds. pr. foot, ...		23,040 "
From this take Haupt & Co's work, say, ...	300 c. yds,	
And Commonwealth's work, say,	5,700 "	
		6,000 "
Which leaves to be taken out in enlargement,		17,040 c. yds.

And at $\frac{9}{16}$ of a cubic yard per man per day, and an average force of 100 men, the time required to complete the enlargement of this division of the Tunnel, 300 working days, or say 12 months.

Central Shaft.—There remains of this shaft to be sunk 640 feet, which, at 20 feet per month, will take 32 months to reach the floor of the Tunnel.

West End.—It is not easy to assign a rate of progress for this part of the work, as unexpected difficulties may retard it, but 35 feet per month should be a safe estimate of its advance, and this rate will also be assumed for the west working of the West Shaft. Upon the above data, we can see where the several parts of the work will be at certain dates, counting, we will say, from the 1st of January, 1867, now at hand.

September 1, 1867.—If eight months be sufficient to complete the *East End* enlargement, on September 1, 1867, it should be done, and the heading and enlargement ready on that date, to go forward together. The *Central Shaft* on the same date will, at 20 feet per month, have made 160 feet down, and have 480 feet to go down to grade.

The *West Shaft* enlargement will be two-thirds completed. The *West End* drifting and arching will have advanced 280 feet eastward, and to a distance of 460 feet from the West Portal.

January 1, 1868.—If we allow 65 feet per month for the progress of the *East End* work, it will at this date have moved 260 feet westward, and have reached 3,760 feet from the East Portal.

The *Central Shaft* will be 80 feet farther down, and have only 400 feet to go. The *West Shaft enlargement* in both directions, will be finished. The *West End arch* will have moved 140 feet east, and made a total progress of 600 feet, from the West Portal.

September 1, 1869.—*East End* work advance in the 20 months since the previous date, 1,300 feet.

Central Shaft down to grade and ready to tunnel both ways. *West Shaft, eastward*, work, at say 48 feet per month, will have gone 960 feet, and its *westward* work at 35 feet per month, 700 feet. *West End arch* will at the same rate of 35 feet per month, have also advanced 700 feet eastward, and a total distance of 1,300 feet from the West Portal. These two workings will meet at this time.

July 1, 1875.—*East End* work in the five years and ten months since the last date, will have progressed (at a fraction less than 60 feet per month,) 4,611 feet westward. *Central Shaft, east*, working at 45 feet per month, will have advanced eastward, a distance of 3,150 feet, and have met the work from East End, and consequently, completed the Tunnel east of this shaft. *West* working of Central Shaft will, at 45 feet per month, have advanced westward 3,150 feet at this date. *West Shaft, east* working. Inasmuch as the Tunnel as above stated should be opened through from the West Portal to this working, on September 1, 1869, a rate of progress fully equal to that of the East End will then be realized from that date onward; and in the $5\frac{10}{12}$ years from September 1, 1869, to July 1, 1875, a fraction over 66 feet per month will make it meet the west working from the Central Shaft, and so complete the Tunnel.

In these estimates of time, I have assumed hand labor to be the agent, and I feel fully warranted in allowing the several rates of speed in the several workings, from which the result is deduced, that the Tunnel can be finished in eight and one-half years, from January 1, 1867. If I have allowed somewhat too short a time for the enlargement of the present work at the East End, there is margin enough in the other estimates of progress to make up for this deficiency. Increase of speed

from the drilling machine, and the use of nitro-glycerin, may largely increase this margin.

PROBABLE COST OF THE WORK TO BE DONE.

If the contract system be applied to the several divisions of the work as above suggested, I am of opinion that with the effective machinery already furnished by the State, with such additions at the Central and West Shafts as may be required, and with proper competition between able and experienced contractors, the work can be let at prices which will produce results as favorable as the following estimate exhibits. It will require probably two months from now to reorganize the work on this new contract basis; but as, if my recommendations in regard to changes in the manner of prosecuting the work be adopted, the enlargement could be commenced immediately, I will assume for simplicity's sake the same prices for what work may be done by the Commonwealth in the interim.

The area of the Tunnel *in rock*, requiring no lining, will, as above, be taken at 54 square yards, for the purpose of this estimate, or at 18 cubic yards per foot, linear. As it is not possible at this time to say how much beyond the west heading of the West Shaft the Tunnel can be carried through rock not needing support, I will assume that an arch of brick or stone will be wanted for its protection for the whole distance west of that heading; but as the lining will not probably be so costly for some distance beyond that point, I will not apply the same price throughout this section of the Tunnel. I will estimate this part of the work by the linear foot (and not by the cubic yard,) having reference to the prices now paid the contractor, who is carrying it on for a part of the distance.

The whole length of the Tunnel between the Portals being, say, 24,862 feet, or $4\frac{709}{1000}$ miles, and the length assumed to require arching, being 2,004 feet at the West End, there will remain 22,858 feet, which, at 18 cubic yards per foot, give . . . . . 411,444 cubic yds.

From this deduct the cubic yards already removed, and amounting as above approximately estimated, to . . .	32,000	"
Leaving to be removed from the body of the tunnel, ...	379,444	"

Of which the enlargement now ready to be made contains, ...	54,000 cubic yds.
Leaving in the untouched part of the tun'l,	325,444 "

Different prices will, of course, be applied to these two last items, but an average price will be taken for the heading and bottoming in the unbroken part of the Tunnel.

ESTIMATE OF COST.

54,000 cubic yards in enlargements at $5, .	$270,000 00
325,000 " " heading and bottom, at an average of $7.50, ...	2,437,500 00
7,638 c. y'ds in remainder of c'ntral shaft, $30,	226,140 00
1,000 ft. linear at west end, next portal, $400,	400,000 00
1,000 " " " " " " shaft, $300,	300,000 00
	$3,633,640 00

Making three million six hundred thirty-three thousand six hundred and forty dollars.

I add nothing for *contingencies*, because in estimates of this description, the prices assumed are not sufficiently *exact* in their character as to make such allowance necessary, or rather the contingencies are supposed to be covered by the prices. The contingencies affecting this particular work are, indeed, with our present experience of its nature, not of a very doubtful or indefinite kind. We know well now what sort of rock we have to blast, and the only serious question is, how much or how little water must we pump out of the two shafts? It is my belief that the work can be let to responsible contractors for the prices above assumed, and that is all that can be said at the present. They bear a fair relation to the prices prevailing before the war, and the suspension of specie payments, and with the prospect of a gradual return to such payments, and consequently a general reduction in the values of labor and material, I think they will be regarded as sufficient by parties bidding for the work, and who will necessarily, for work of such magnitude, be of the most experienced and judicious class.

Conclusion.

It is my hope that what I have above presented may be considered as a sufficient performance on this occasion of my duty as your Consulting Engineer. It was my wish to have submitted, in addition, some remarks upon the character and value of this great work, as a part of the railway system of the Commonwealth, but time will not permit me at present to say more than that, in view of its unparalleled magnitude and consequent cost, it should not be considered *by itself*, but in connection, not only with the entire line of which it forms a part within the State of Massachusetts, but as a necessary link in a chain of interior communication, extending even to the most distant source of trade to the Commonwealth and her capital. If viewed in this light, the extraordinary expense involved in this monument of State enterprise and laudable State pride, will be lost sight of, except as another example of what Massachusetts can do when she is determined.

Most respectfully, your obedient servant,

BENJ. H. LATROBE,
Consulting Engineer.